GE

Measurement & Control

Gas Analysis

FGA 311

User's Manual

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910-160 Rev. E
July 2012

FGA 311

In Situ Flue Gas Oxygen Transmitter

User's Manual

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July 2012

www.ge-mcs.com

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Information Paragraphs

- **Note** paragraphs provide information that provides a deeper understanding of the situation, but is not essential to the proper completion of the instructions.
- **Important** paragraphs provide information that emphasizes instructions that are essential to proper setup of the equipment. Failure to follow these instructions carefully may cause unreliable performance.
- **Caution!** paragraphs provide information that alerts the operator to a hazardous situation that can cause damage to property or equipment.
- **Warning!** paragraphs provide information that alerts the operator to a hazardous situation that can cause injury to personnel. Cautionary information is also included, when applicable.

Safety Issues

WARNING! It is the responsibility of the user to make sure all local, county, state and national codes, regulations, rules and laws related to safety and safe operating conditions are met for each installation.

Auxiliary Equipment

Local Safety Standards

The user must make sure that he operates all auxiliary equipment in accordance with local codes, standards, regulations, or laws applicable to safety.

Working Area

WARNING! Auxiliary equipment may have both manual and automatic modes of operation. As equipment can move suddenly and without warning, do not enter the work cell of this equipment during automatic operation, and do not enter the work envelope of this equipment during manual operation. If you do, serious injury can result.

WARNING! Make sure that power to the auxiliary equipment is turned OFF and locked out before you perform maintenance procedures on the equipment.

Qualification of Personnel

Make sure that all personnel have manufacturer-approved training applicable to the auxiliary equipment.

Personal Safety Equipment

Make sure that operators and maintenance personnel have all safety equipment applicable to the auxiliary equipment. Examples include safety glasses, protective headgear, safety shoes, etc.

Unauthorized Operation

Make sure that unauthorized personnel cannot gain access to the operation of the equipment.

Environmental Compliance

Waste Electrical and Electronic Equipment (WEEE) Directive

GE Measurement & Control is an active participant in Europe's *Waste Electrical and Electronic Equipment* (WEEE) take-back initiative, directive 2002/96/EC.

The equipment that you bought has required the extraction and use of natural resources for its production. It may contain hazardous substances that could impact health and the environment.

In order to avoid the dissemination of those substances in our environment and to diminish the pressure on the natural resources, we encourage you to use the appropriate take-back systems. Those systems will reuse or recycle most of the materials of your end life equipment in a sound way.

The crossed-out wheeled bin symbol invites you to use those systems.

If you need more information on the collection, reuse and recycling systems, please contact your local or regional waste administration.

Visit http://www.ge-mcs.com/en/about-us/environmental-health-and-safety/1741-weee-req.html for take-back instructions and more information about this initiative.

Chapter 1. General Information

1.1 Introduction

The *FGA 311 In Situ Flue Gas Oxygen Transmitter* monitors the combustion efficiency of a boiler or furnace by measuring the percentage of oxygen in the flue gases. This self-contained instrument is installed so that its zirconium oxide oxygen sensor is located directly in the stream of the flue gases. The measurements may be recorded via the built-in 4-20 mA output or transmitted to a computer terminal via the built-in RS232 interface.

The FGA 311 is available with either the standard *weatherproof* enclosure or the optional *explosion-proof* enclosure, as shown in *Figure 1 on page 2*. However, the operation and the internal components are the same for both configurations.

The FGA 311 consists of the following sub-assemblies:

- An aluminum *enclosure*, which includes a breather port, the unit's mounting threads, a calibration gas connection and a reference air connection. In addition, the enclosure houses the printed circuit board and provides two ports for electrical conduit or cable glands.
- All of the electrical components, including the replaceable fuse, are mounted on the *printed circuit board* (PCB). All electrical connections for the line power, 4-20 mA recorder output and RS232 interface are made to the PCB.
- A *probe assembly* that extends into the flue gas stream.
- A *heater sub-assembly* that maintains the oxygen sensor at the proper operating temperature for efficient operation.
- A zirconium oxide *oxygen sensor* to measure the percentage of oxygen in the flue gases.
- A *filter assembly* that protects the oxygen sensor from particulates in the flue gas stream.

The FGA 311 has been designed to permit troubleshooting, maintenance and adjustment of the instrument without removing the unit from the flue.

1.1 Introduction (cont.)

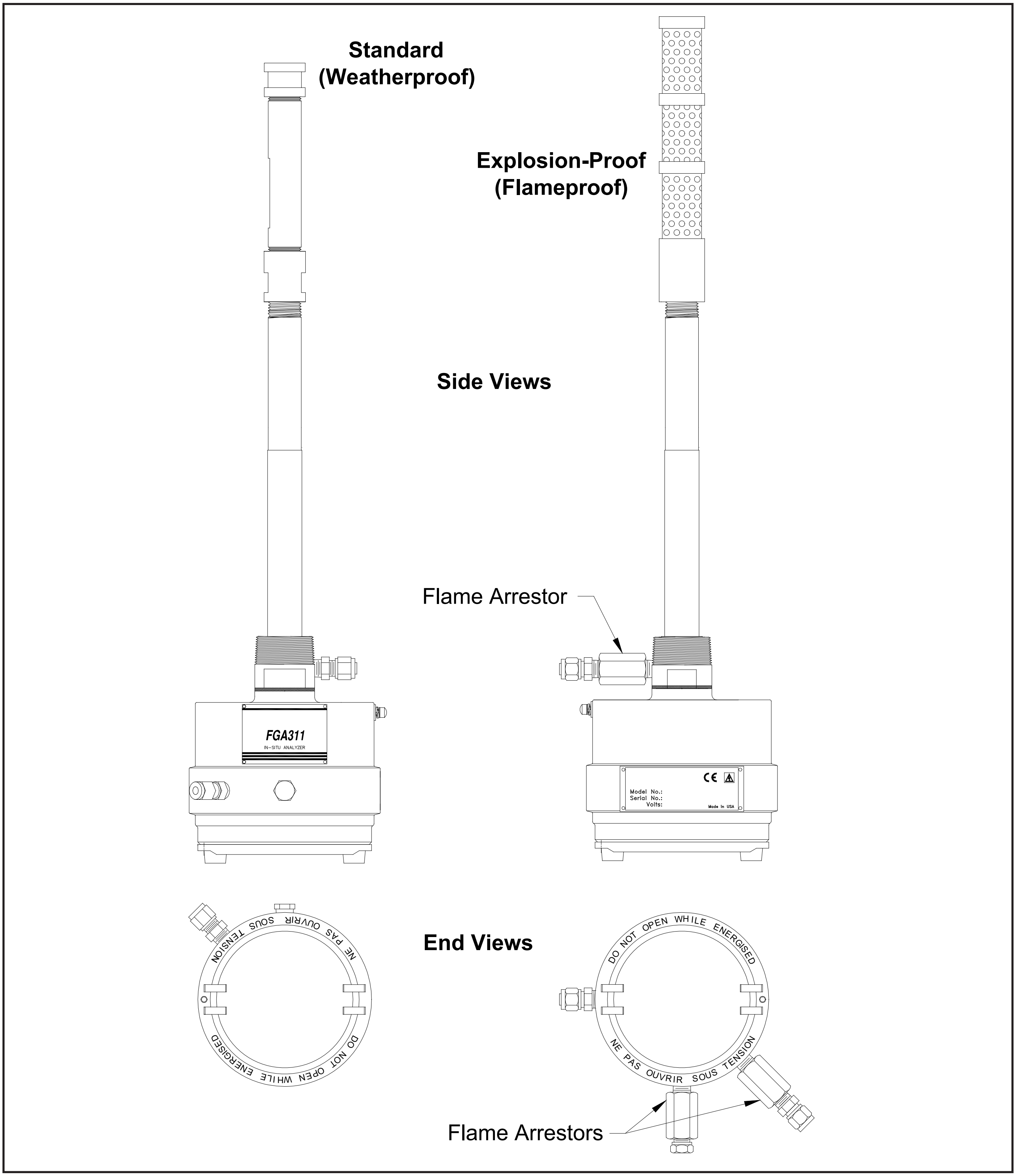

Figure 1: The FGA 311 Enclosures

1.2 Principles of Operation

In an ideal combustion process, a precise ratio of air to fuel is burned efficiently to yield only heat, water vapor, and carbon dioxide. However, because of burner aging, imperfect air to fuel mixtures, variable firing rates and/or inaccurate ignition timing, this situation rarely happens.

A sure sign of a less than ideal combustion process is the presence of excess oxygen in the flue gases. The level of this excess oxygen is easily monitored with the FGA 311 In Situ Flue Gas Oxygen Transmitter, and the information can then be used to make the necessary adjustments to improve the efficiency of the combustion process. The following two major components are included in the FGA 311 analyzer:

- a zirconium oxide oxygen sensor
- a loop-controlled heater circuit

These components are described in the sections that follow.

1.3 The Oxygen Sensor

The inside and outside of the zirconium oxide oxygen sensor are coated with a porous platinum catalyst, forming two electrodes. Flue gases flow past the outside of the sensor, while atmospheric air circulates freely on the inside of the sensor. The atmospheric air is used as the reference gas for the oxygen measurements. See the oxygen sensor sub-assembly shown in *Figure 2*.

At the normal operating temperature (650° to 1100°C) of the sensor, the oxygen molecules in the atmospheric reference air (20.93% oxygen) are electrochemically reduced at the inner electrode. The resulting oxygen ions seek an equilibrium with the lower oxygen concentration on the sample gas side of the sensor, by migrating through the porous ceramic toward the outer electrode.

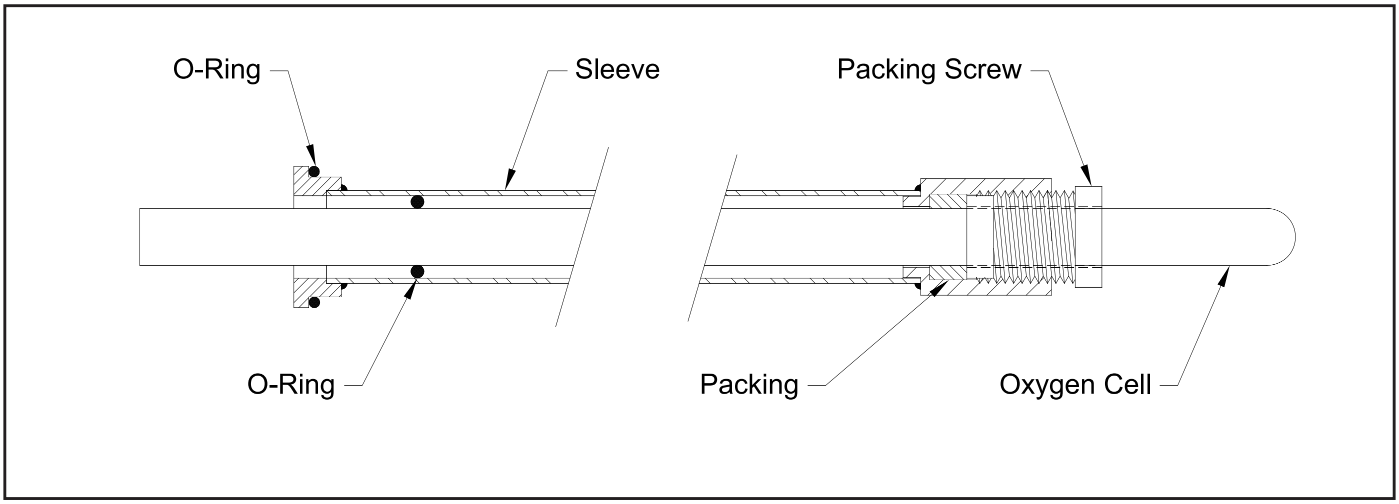

Figure 2: The FGA 311 Oxygen Sensor

1.3 The Oxygen Sensor (cont.)

At the outer electrode, the oxygen ions give up their extra electrons and revert to oxygen molecules, before being swept away by the flue gas stream. This exchange of electrons at the electrodes generates a voltage gradient across the sensor. See *Figure 3*.

The lower the concentration of oxygen in the flue gases, the greater the rate of ion migration through the ceramic and the higher the resulting voltage gradient across the sensor. In fact, the sensor's voltage output rises logarithmically as the percentage of oxygen in the flue gases decreases. This enables the FGA 311 to accurately measure very small levels of oxygen in the flue gases.

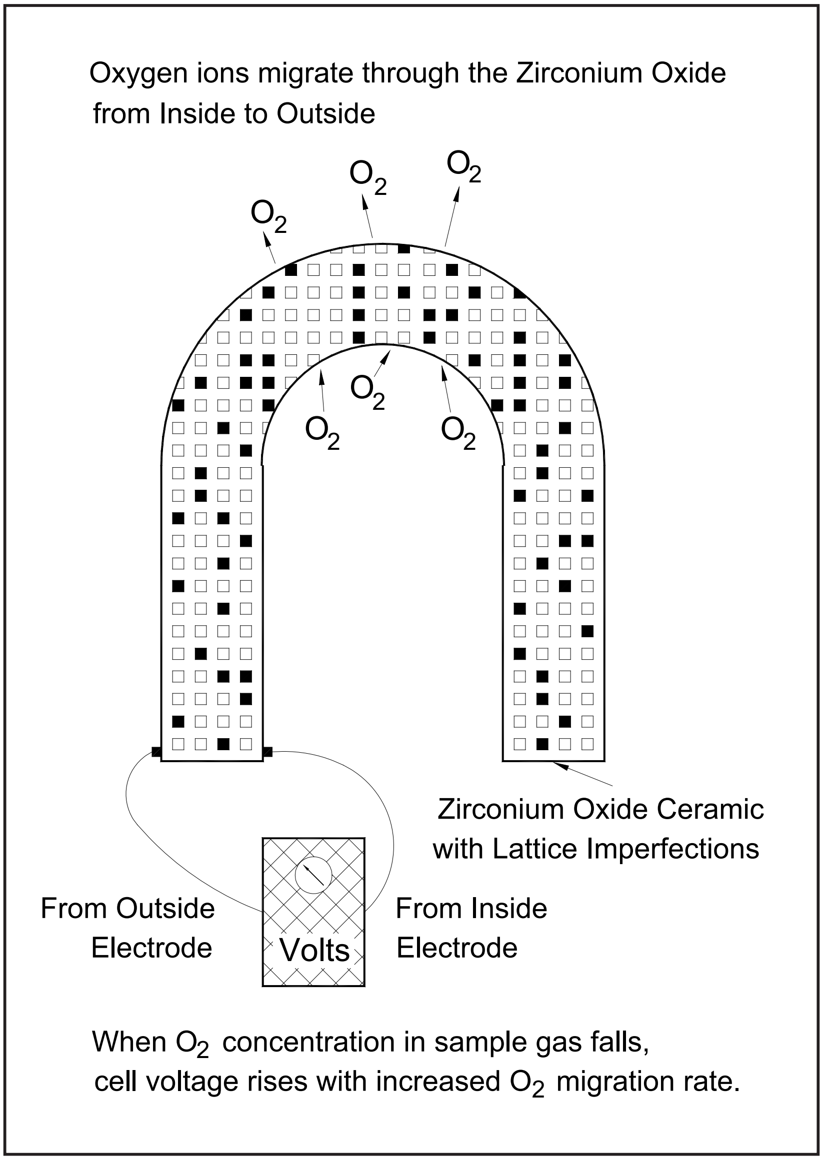

Figure 3: Oxygen Migration Through the Sensor

1.4 The Heater Control Circuit

The oxygen sensor temperature in the FGA 311 is maintained by a heater, which is part of a complex temperature control loop. This circuit constantly monitors the oxygen sensor temperature, compares it to the set point temperature (700°C), and turns the heater ON or OFF accordingly. The specific type of control circuit used is called a Proportional Integral Derivative (**PID**) loop, because of the three adjustable parameters involved:

- Proportional Band: Because the system cannot respond instantaneously to temperature changes, the actual temperature of the oxygen sensor oscillates about the set point. In general, increasing the proportional band reduces the magnitude of these temperature oscillations.
- Integral Action: A consequence of increasing the proportional band is the introduction of an offset between the set point and the control point. The integral portion of the control loop acts to move the control point back toward the set point within a specified period of time. Thus, decreasing this integration time reduces the offset more quickly.
- Derivative Action: The derivative portion of the control loop applies a corrective signal based on the rate at which the actual temperature is approaching the set point. In effect, the derivative action reduces overshoot by counteracting the control signal produced by the proportional and integral parameters.

The heater control circuit is configured at the factory for optimum performance. Because of the strong interaction between the three parameters involved, properly setting up the PID loop is a very complex matter. As a result, randomly changing the P, I and/or O parameters can seriously degrade the performance of the FGA 311.

IMPORTANT: *Always contact GE before attempting to change the default P, I or O values.*

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Chapter 2. Installation

2.1 Introduction

This chapter gives directions for installing and wiring the FGA 311. The following specific topics are included:

- unpacking the unit
- selecting the site
- mounting the analyzer
- wiring the analyzer

WARNING! To ensure safe operation of the FGA 311, it must be installed and operated as described in this manual. In addition, be sure to follow all applicable local safety codes and regulations for installing electrical equipment.

2.2 Unpacking the Unit

Remove the analyzer from its shipping container and make sure that all items on the packing slip have been received. If anything is missing, contact the factory immediately. The analyzer, as shown in *Figure 4*, is shipped fully assembled and ready to install.

CAUTION! When unpacking the analyzer, be careful not to damage the probe. It is covered with a porous ceramic filter that will easily crack if it is knocked against a hard surface.

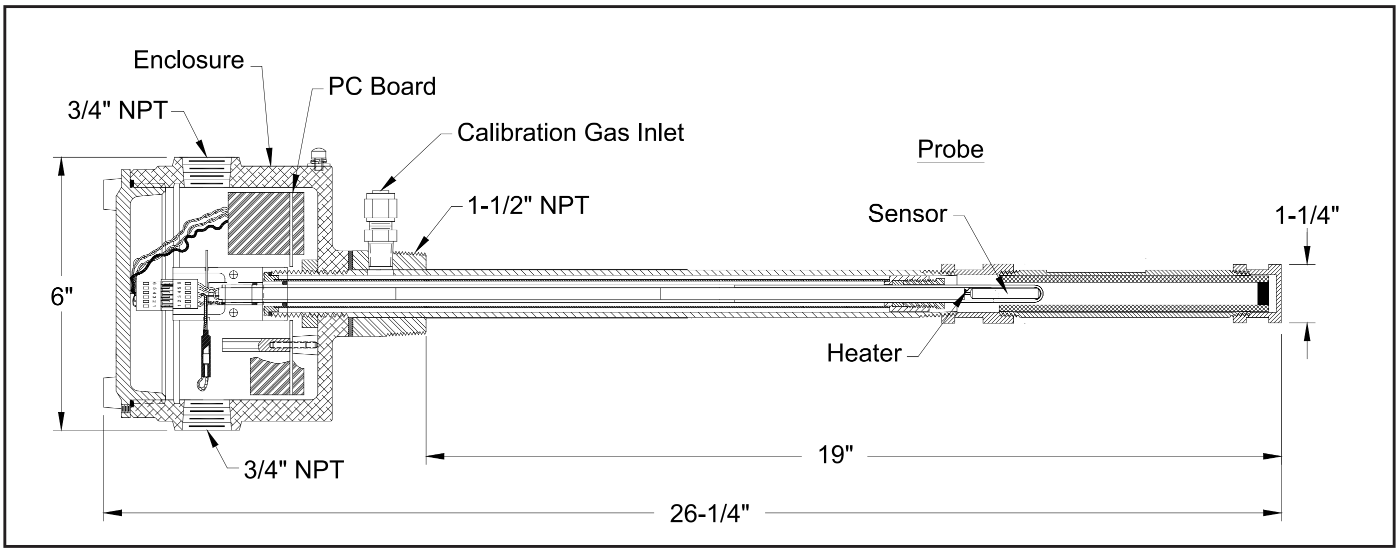


Figure 4: The FGA 311 In Situ Flue Gas Analyzer

2.3 Line Power Requirements

Each FGA 311 analyzer is factory-configured for the proper line voltage, as specified at the time of purchase. The available options include the following:

- Japan = 100 VAC
- U.S.A. = 110/120 VAC
- Europe = 220 VAC
- Australia = 240 VAC.

CAUTION! To change the line voltage to the unit, contact the factory for instructions. DO NOT make such a change without first obtaining proper instructions.

2.4 Selecting the Site

Environmental and installation factors should already have been discussed with a GE applications engineer or field sales person before the FGA 311 arrives. The analyzer must be installed either in a furnace or boiler wall or in a flue duct. Ideally, the end of the probe assembly should extend approximately 1 ft (30.5 cm) into the flue gas stream. Also, the analyzer should be positioned so that the probe holes are on the downstream side of the probe (see *Figure 5 on page 11*).

- For *furnaces*, locate the analyzer close to the combustion zone, typically within the radiant section and always before the convection section. Make sure that the probe's maximum operating temperature is not exceeded and that the probe is not situated in a non-homogeneous flue gas mixture.

IMPORTANT: *If the ambient temperature in the vicinity of the probe can exceed 650°C (1202°F), a high temperature probe assembly is required.*

- For *boilers*, locate the analyzer downstream of the heat exchanger and just before the economizer air heater, if one is installed. The analyzer should not be placed downstream of any air heater, because of possible air leaks that can cause inaccurate readings.

In general, the sample point should be an area of *high turbulence*, which will ensure a good homogeneous mixture of the flue gases. Conditions to be avoided would include *air leaks* upstream of the sample point and *dead spaces* in the vicinity of the sample point.

2.5 Bench Testing

The analyzer was not designed to be calibrated outside the flue. If you decide to operate it outside the flue, please note:

- It will take at least two hours to give reasonable numbers for verification.
- Many times you will get a “heater open” message, due to the fact that the unit has not reached the operating temperature in the allotted time. Power down and then power up again.
- Any change in calibration will result in re-calibration once the analyzer is installed in the flue.

2.6 Mounting the Analyzer

The FGA 311 has integral male 1-1/2” NPT mounting threads. This permits a flange to be threaded onto the analyzer, and the resulting assembly is then bolted to a mating flange on the furnace/boiler wall or flue duct.

Note: *For installations where the FGA 311 may be exposed to water or other fluids, install the unit with the breather (see* Figure 5 on page 11*) facing downward.*

Do not use any thread sealant during the installation. Upon heating, Teflon tape will melt and other sealants may emit gases that interfere with the oxygen readings.

Carefully follow the steps below to mount the FGA 311 In Situ Flue Gas Oxygen Transmitter. The unit may be mounted in either a horizontal or vertical orientation.

IMPORTANT: *Direct mounting of the FGA 311 into a threaded hole using its mounting threads is not recommended. Always use a mounting flange.*

To prepare the installation site for mounting the analyzer, complete the following preliminary steps:

1. Fasten a short section of pipe having at least a 2” inside diameter into the process wall.

IMPORTANT: *Make sure that the pipe is long enough to permit installation of the flange mounting hardware and that the flange is oriented with its bolt holes straddling the vertical and horizontal center lines.*

2. Weld a mating flange onto the end of the pipe, as shown in Figure 5 on page 11.

Note: *Standard available factory options include 3”-300 lb ANSI, 4”-150 lb ANSI and DN80 PN16 mounting flanges. A separate mating flange can also be supplied with the unit.*

2.6 Mounting the Analyzer (cont.)

Before mounting the FGA 311 analyzer assembly onto the mating flange, mark the enclosure in line with the probe holes. Then, complete the following steps:

IMPORTANT: *The probe holes must be positioned on the downstream side of the probe. See* Figure 5 on page 11 *for the proper orientation.*

1. Slide the gasket over the probe assembly and up against the mounting flange on the analyzer.

Note: Be sure to use a suitable high temperature gasket for this application.

2. Orient the analyzer so the probe holes are properly positioned on the downstream side of the probe, and slide the probe through the hole in the mounting wall until the two flanges meet.

3. Secure the analyzer in place by fitting bolts into the matching flange mounting holes and fastening the bolts with nuts and washers. Make sure that the gasket is properly positioned between the two flanges.

This completes the mounting of the FGA 311. The required external connections are discussed in the following sections.

2.6 Mounting the Analyzer (cont.)

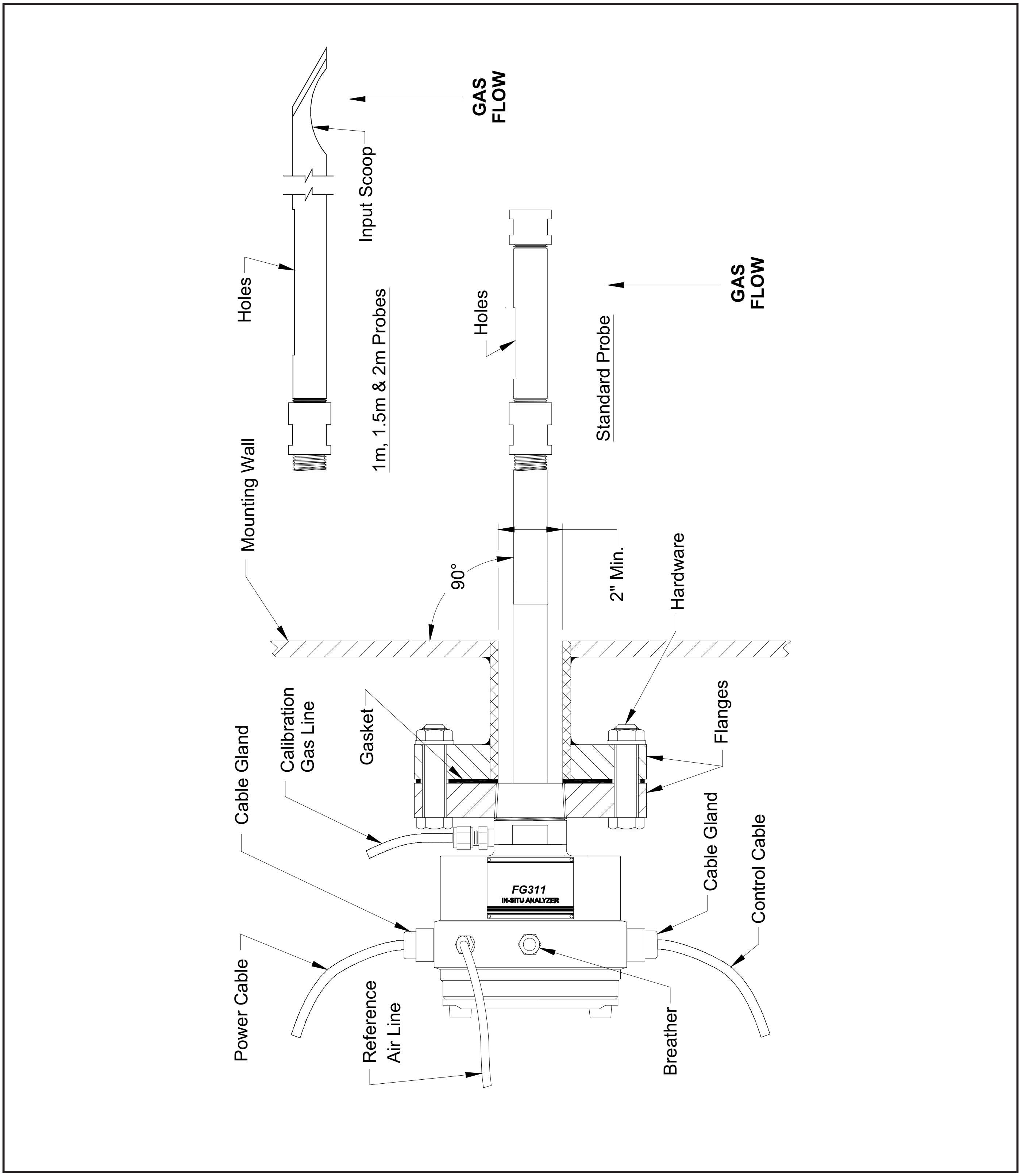


Figure 5: Flange Mounting the FGA 311

2.7 Wiring the Analyzer

Connect the power and control signal wiring as described below and as shown in *Figure 6 on page 13*, which shows the printed circuit board mounted within the open FGA 311 enclosure. The necessary connectors are supplied with the unit, and they are plugged into the mating connectors on the printed circuit board prior to shipment.

CAUTION! DO NOT power up the unit until instructed to do so!

CAUTION! To meet CE Mark requirements, all electrical cables must be installed as described in *"CE Mark and Regulatory Compliance" on page 79*.

2.7.1 Wiring the Line Power

Use one of the 3/4" NPT connections on the enclosure for installation of the power cable gland or conduit. The FGA 311 has been preset at the factory for the line voltage specified at the time of purchase. Never connect a different line voltage to the unit without first obtaining instructions from the factory.

WARNING! Improper connection of the power line or connection to the wrong voltage may result in an electrical hazard.

Note: *For compliance with the European Union's Low Voltage Directive (73/23/EEC), this unit requires an external power disconnect device such as a switch or circuit breaker. The disconnect device must be marked as such, clearly visible, directly accessible, and located within 1.8 m (6 ft) of the unit.*

The FGA 311 is designed to comply with the LVD Directive per the requirements of EN 61010 with the following exception: The 230 VAC unit passes with a test voltage of 1,800 VAC. (Refer to Table D.10 of Annex D in EN 61010.)

Connect the line power to terminal block TB1, as shown in *Figure 6 on page 13*, by completing the following steps:

1. Connect the LINE (black) lead to pin #1 on TB1.
2. Connect the NEUTRAL (white) lead to pin #2 on TB1.
3. Connect the GROUND (green) lead to the earth ground screw inside the enclosure.

Proceed to the next section to wire the control signals.

2.7 Wiring the Analyzer (cont.)

Heater Connections J3 Terminal Block	
Pin	Description
1	Heater
2	No Connection
3	Heater

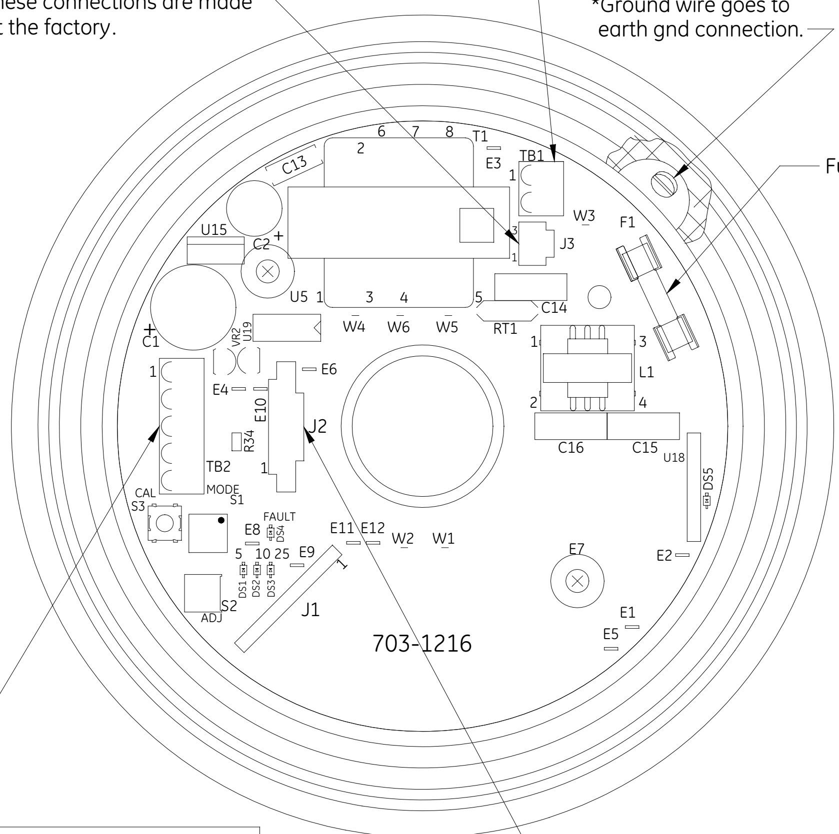
NOTE: These connections are made at the factory.

TB1 Power* Terminal Block	
Pin	Description
1	Line
2	Neutral

Power Voltage Options Factory Installed		
Power	Jumpers	Fuse
115V	W1,W3,W4,W5	1/2A
230V	W2,W6	1/4A

*Ground wire goes to earth gnd connection.

Fuse



RS232 Analog Output TB2 Terminal Block		
Pin	Description	
1	Return	RS232
2	Receive	
3	Send	
4	4-20 mA Out–	
5	4-20 mA Out+	

Thermocouple and Sensor J2 Terminal Block	
Pin	Description
1	Thermocouple +
2	Thermocouple –
3	Zirconium Oxide Oxygen Sensor +
4	Zirconium Oxide Oxygen Sensor –
5	Future Use (CJC+)
6	Future Use (CJC–)

NOTE: These connections are made at the factory.

NOTES:

1. PC Board may be oriented differently, depending on how the unit is installed.
2. J1 is reserved for future use.

(Shown with sensor/heater assembly and cable removed for clarity.)

Figure 6: Connections to the FGA 311 PC Board

2.7.1 Wiring the Control Signals

Use the remaining 3/4" NPT port on the FGA 311 enclosure for connecting the control cable gland or conduit. For cable runs of less than 5 m (16.4 ft), standard twisted pair cable may used for these connections. However, shielded cable should be used for longer cable lengths or for CE Mark compliance.

IMPORTANT: *This symbol indicates Caution - risk of electric shock:*

The control signal connections are made to the printed circuit board on terminal block TB2, as shown in *Figure 6 on page 13*. To make the necessary connections, complete the following steps:

1. Connect the RS232 serial port leads to TB2 as follows:

Note: Before the FGA 311 may be programmed using its built-in RS232 interface, the serial port of the personal computer (PC) must be configured to the following specifications: 9600 Baud, 8 Data Bits, 1 Stop Bit, Non-Parity, Xon/Xoff Flow Control

Note: The serial port connection should be made with a GE #704-668 cable assembly or its equivalent. To assemble an equivalent cable, refer to Figure 23 on page 78 *of this manual.*

- **a.** Connect the Ground lead (the green wire from pin #5 of the DB9 connector on the PC) to pin #1.
- **b.** Connect the Receive lead (the red wire from pin #2 of the DB9 connector on the PC) to pin #2.
- **c.** Connect the Transmit lead (the white wire from pin #3 of the DB9 connector on the PC) to pin #3.

2. Connect the 4-20 mA analog output leads to TB2 as follows:

- **a.** Connect the 4-20 mA Return (-) lead to pin #4.
- **b.** Connect the 4-20 mA Signal (+) lead to pin #5.

Proceed to the next section for a description of the internal, factory-installed wiring.

2.7.2 Factory Connections

In addition to the user connections described above, the following connections are made at the factory to terminal blocks J2 and J3.

- Thermocouple connections to J2 on pins #1 (+) and #2 (-).
- Oxygen sensor connections to J2 on pins #3 (+) and #4 (-).
- Heater connections to J3 on pins #1 and #3.

For reference purposes only, these factory connections are shown in *Figure 6 on page 13*.

2.8 Reference Air and Calibration Gas Lines

During normal operation, the FGA 311 requires a constant supply of a reference air for the zirconium oxide oxygen sensor. The recommended gas for this purpose is instrument air (containing 20.93% oxygen) at a flow rate of 20-50 cc/min. Connect this gas supply, with 1/4" tubing and a valve to control the flow, to the 1/4" compression fitting provided. Refer to *Figure 7 on page 16* for the location of this connector.

Also, a separate gas supply is required for calibration of the instrument. This line should be connected, with 1/4" tubing and a valve to control the flow, to the remaining 1/4" compression fitting on the FGA 311. See *Figure 7 on page 16* for the location of this connector.

Note: *The calibration gas port must remain capped, if no permanent plumbing is attached. See* "Calibration" on page 37*, for a discussion of the recommended calibration gases and procedures.*

In addition to the basic reference air and calibration gas lines, a variety of ancillary equipment is recommended. A typical system that will ensure efficient and reliable operation of the FGA 311 is illustrated in *Figure 7 on page 16*.

2.8 Reference Air and Calibration Gas Lines (cont.)

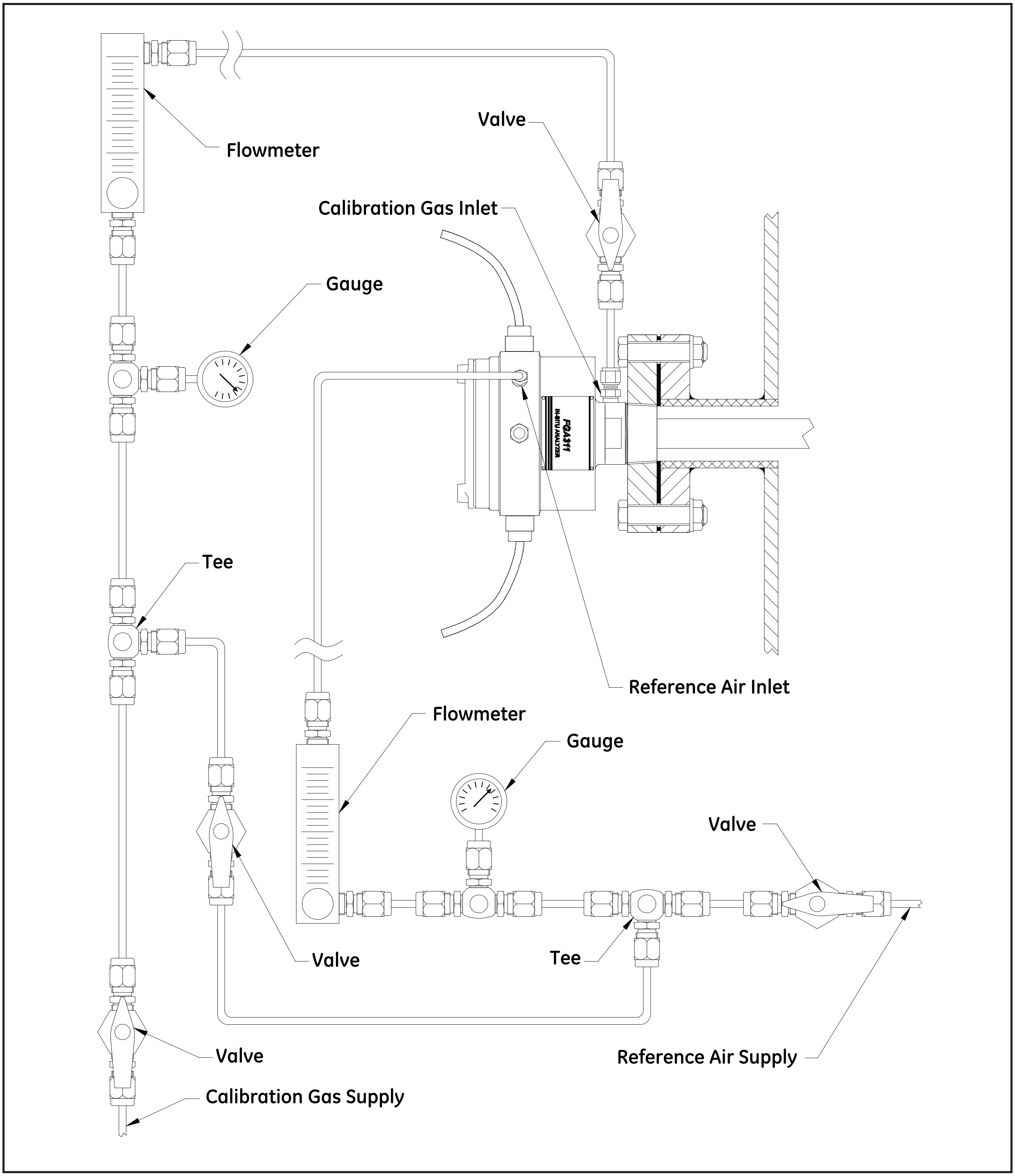


Figure 7: A Typical FGA 311 System

Chapter 3. Operation and Programming

3.1 Introduction

Because the FGA 311 In Situ Flue Gas Oxygen Transmitter is a monitoring device, operation of the installed analyzer is simple. Once it has been properly installed and set up, it will simply begin taking readings. However, the analyzer should be allowed to warm up for at least one hour (three hours if possible) prior to use. See *"Installation" on page 7*, if all of the required installation requirements have not yet been completed.

Calibration of the unit should be checked once or twice a week for the first month of operation and once every 2-3 months thereafter. See *"Calibration" on page 37* for the correct procedures.

WARNING! To ensure safe operation of the FGA 311, it must be installed and operated as described in this manual. In addition, be sure to follow all applicable local safety codes and regulations for installing electrical equipment

3.2 Preventing Common Problems

Because of the extreme conditions in monitoring flue gases and the complexity of the FGA 311 measurement techniques, some simple precautions should be taken with the instrument. Failure to observe these basic procedures can lead to operational difficulties. Compliance with the following instructions will help to eliminate such common problems:

- Do not use pipe thread compounds on any part of the FGA 311. Many pipe thread compounds emit combustible vapors that may cause inaccurate readings.
- Do not handle the sensor assembly any more than is absolutely necessary. Although some scratches on the platinum electrode can be tolerated, rubbing the coating should be avoided. Also, the transfer of skin oils to the electrode can cause erroneous readings.
- Scrubbing the sensor while washing it or washing a hot sensor can damage or destroy it. Clean the sensor only by rinsing it with clean water, after the sensor has cooled.
- Installing a cold probe assembly into a hot flue gas stream can cause damage to the filter and/or sensor. Always allow the probe assembly to gradually heat up to normal operating temperature, before subjecting it to hot flue gases.

If any problems not covered in this manual are encountered, contact GE for assistance.

3.3 Powering Up

Before powering up the unit, start the flow of reference air. Be sure that the reference air source is connected to the correct port, as shown in Figure 2-4 on page 2-9. The recommended reference air is instrument air (20.93% oxygen) at a flow rate of 20-50 cc/min.

Note: *The zirconium oxide oxygen sensor can not provide accurate readings without a known oxygen percentage on the reference side of the cell. Allow the reference air to flow for at least five minutes prior to operation.*

Power may now be applied to the unit. Since the FGA 311 does not have its own power switch, the main disconnect must be used to power the analyzer on. Simply place this switch in the ON position, and allow the analyzer to warm up for at least one hour (three hours if possible) before taking any readings.

Note: *For compliance with the European Union's Low Voltage Directive (73/23/EEC), this unit requires an external power disconnect device such as a switch or circuit breaker. The disconnect device must be marked as such, clearly visible, directly accessible, and located within 1.8 m (6 ft) of the unit.*

The FGA 311 is designed to comply with the LVD Directive per the requirements of EN 61010 with the following exception: The 230 VAC unit passes with a test voltage of 1,800 VAC. (Refer to Table D.10 of Annex D in EN 61010.)

The red fault light (DS4) and one of the green oxygen range indicators (DS1, DS2 or DS3) on the printed circuit board will blink until the FGA 311 has reached its normal operating temperature of 700°C. Then, the fault light will go out and the range indicator will glow steadily.

3.4 Taking Measurements

After the FGA 311 has warmed up, the voltage output of the zirconium oxide oxygen sensor will vary logarithmically with the oxygen concentration in the flue gases, according to the Nernst equation (see *"The Nernst Equation" on page 69* for details):

$$E(mV) = 48.274 \bullet \log\left[\frac{20.93}{\%O_2}\right] \tag{1}$$

In *Equation 1*, "E" is the voltage in millivolts generated by the sensor at an operating temperature of 700°C.

The built-in thermocouple temperature sensor in the FGA 311 automatically adjusts the constant used in the Nernst equation to reflect the precise actual temperature of the oxygen sensor. In addition, the non-linear output voltage signal generated by the oxygen sensor is internally converted into a linear 4-20 mA output current signal, which is sent to pins 4 and 5 of terminal block TB2. The 4-20 mA current range corresponds to a flue gas oxygen range of 0% to the programmed O_2 range (5, 10 or 25%). By connecting a digital ammeter or a recording device to these terminals, the oxygen content of the flue gases may be continuously monitored.

3.5 Data Records

"Data Records" on page 81 provides several tables for entering all of the relevant data pertaining to the installation and programming of the FGA 311. Be sure to maintain the accuracy of this data on a regular basis. In the event of problems with the unit, the data records may provide valuable information to assist in the troubleshooting procedure.

3.6 Menu Map

A complete menu map of the FGA 311 built-in software is shown in *Figure 10 on page 35*. Refer to this figure as needed to supplement the step-by-step programming instructions that follow.

3.7 Programming Options

The following two methods for programming the FGA 311 In Situ Flue Gas Oxygen Transmitter may be used to navigate through the *User Program*:

- manual *switches*, which are located inside the enclosure, on the analyzer's printed circuit board
- a *hyperterminal* or *terminal* or *computer*, utilizing the unit's built-in RS232 serial interface

Note: *The entire* EXTRA *menu is not accessible via the manual programming switches.*

3.8 Programming with Manual Switches

Manual programming of the FGA 311 is accomplished with a series of switches and LEDs located on the printed circuit board. These components, which are shown in *Figure 8*, may be accessed by removing the cover from the FGA 311.

Although the menu map shown in *Figure 10 on page 35* does apply to both the manual programming mode and the RS232 programming mode, some of the programming options are not available via the manual switches. Specifically, the entire EXTRA menu can not accessed via the PC board switches.

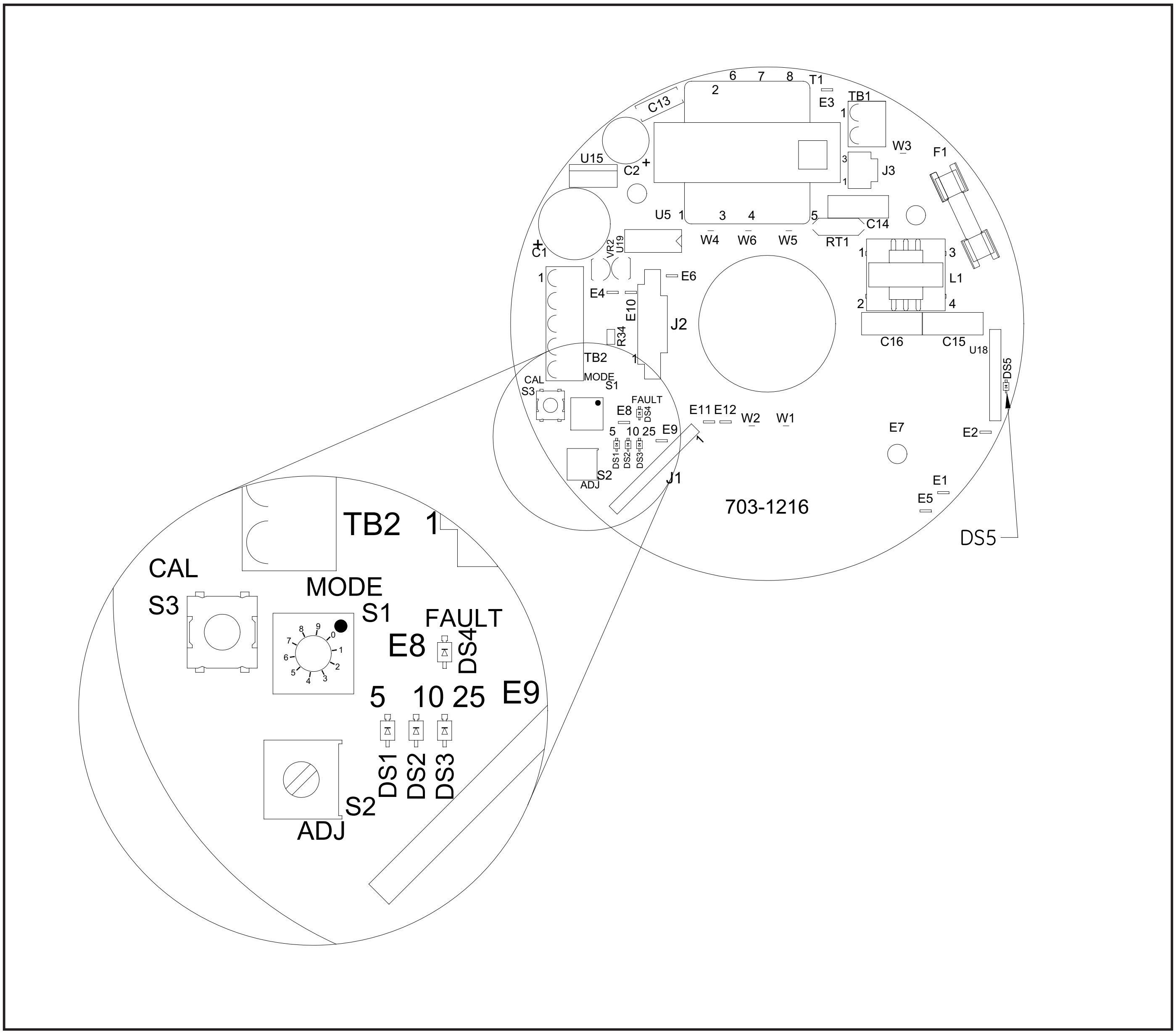


Figure 8: Circuit Board Switches and LEDs

3.8.1 Description of Switches and LEDs

The following switches and lights will be found on the printed circuit board of the FGA 311:

- MODE **Switch S1:** a 10-position rotary switch that is used to select the desired menu option.
- ADJ **Switch S2:** a rotary encoder switch used to adjust the value of numeric menu options selected with Switch S1.
- CAL **Switch S3:** a push-button switch used to enter and exit programming mode and to confirm the programming option set with Switch S1.
- DS1-DS3**:** three green LEDs that are used to indicate the selected oxygen range setting.
- DS4**:** a red LED that is used as a fault indicator.
- DS5**:** a yellow LED that indicates the heater duty cycle.

The specific menu options that may be selected with the 10-position rotary MODE **Switch S1** are listed in *Table 1*.

Table 1: MODE Switch S1 Positions

Switch Position	Menu Option
1	AIR
2	GAS
3	RNG
4	TRIM_O2 4mA
5	TRIM_O2 20mA
6	Not Used
7	Not Used
8	Not Used
9	Not Used

Note: *Only five of the nine positions on Switch S1 (1-5) are currently active. Positions 6–9 are not used at this time.*

Navigating through the FGA 311 built-in *User Program* software is easily accomplished by completing the detailed steps in the following section.

3.8.2 Manual Programming Instructions

Use the following instructions to program the FGA 311 with the printed circuit board switches:

Set Switch S1 = 1	Push CAL Switch S3 and hold for 5 seconds to set the AIR calibration. A green LED will blink until the calibration is complete. Press Switch S3 and hold for 5 seconds to EXIT programming mode.

IMPORTANT: *Always complete the* AIR *calibration before attempting the* GAS *calibration. Also, The red fault LED may glow temporarily during the* GAS *calibration procedure.*

Set Switch S1 = 2	Push CAL Switch S3 and hold for 5 seconds to set the GAS calibration. Adjust the value with ADJ Switch S2 until a green LED starts blinking. Press Switch S3 and hold for 5 seconds to EXIT programming mode.

Note: Refer to "Calibration" on page 37*, for a detailed description of the calibration procedures.*

Set Switch S1 = 3	Push CAL Switch S3 and hold for 5 seconds to access the RANGE option. The current O_2 range LED will blink. Adjust the value with ADJ Switch S2 until the green LEDs start blinking. Press Switch S3 and hold for 5 seconds to EXIT programming mode.

Set Switch S1 = 4	Push CAL Switch S3 and hold for 5 seconds to access the TRIM_O2 4mA option. Adjust the value with ADJ Switch S2 until the output signal reads 4 mA. Press Switch S3 and hold for 5 seconds to EXIT programming mode.

Note: For the TRIM_O2 *function, always adjust the* 4 mA *setting <u>before</u> the* 20 mA *setting. This will ensure optimum accuracy of the instrument.*

Set Switch S1 = 5	Push CAL Switch S3 and hold for 5 seconds to access the TRIM_O2 20mA option. Adjust the value with ADJ Switch S2 until the output signal reads 20 mA. Press Switch S3 and hold for 5 seconds to EXIT programming mode.

IMPORTANT: *After the programming has been completed, reinstall the cover on the FGA 311 enclosure. Do not operate the FGA 311 with the cover permanently removed.*

3.9 Programming from a Computer Terminal

In the following instructions, the actual terminal *screen display* is shown in the left column, while the required *user response* is shown in the right column. Keyboard inputs are indicated by square brackets (i.e. [ESC] means to press the “escape key” on the keyboard). Also, to change a displayed numeric value, use the [+] and [–] keys to adjust the current value to the desired setting.

For reference, the screen display of two typical menu lines is shown in *Figure 9*. The first line shown represents the menu line that appears on the terminal screen as soon as the *User Program* has been accessed. The second line appears after [ESC] is pressed. Note the location of the selection brackets [ ], which highlight the current menu choice.

[ESC]	RUN 20.93	O_2 700°C
[OPTS]	TRIM	EXTRA

Figure 9: Typical Menu Lines

Navigating through the *User Program* is easy, using the keystrokes in *Table 2* and the instructions in the following sections.

Table 2: Computer Terminal Keyboard Entries

Desired Action	Keyboard Entry
Move from run mode to programming mode	[ESC]
Move from programming mode to run mode	[ESC]
Move selection brackets	[SPACE]
Enter numerical data	[+], [-]
Confirm selection or entry	[ENTER]
Start entry over again	[BACKSPACE]
Move up one level in program	[BACKSPACE]

Note: *The use of any keys on the keyboard other than those listed in* Table 2 *will not be recognized by the FGA 311. Any such keyboard entries will simply be ignored by the analyzer. Also,* [+] *is a shifted key, and the* [SHIFT] *key must be held while striking it.*

3.9.1 RS232 Serial Port Settings

Before the FGA 311 may be programmed via its built-in RS232 interface, the serial port of the personal computer (PC) must be configured to the following specifications:

- 9600 Baud
- 8 Data Bits
- 1 Stop Bit
- No Parity
- Xon/Xoff Flow Control

Note: *If the RS232 connection still does not work, try reversing the leads on pins 2 and 3 of terminal block* TB2.

Refer to the computer's documentation for the correct procedures to configure and access the serial port. Then, proceed to the next section to begin programming the analyzer.

3.9.2 OPTS Menu

Use the following procedure to move through the OPTS menu.

RUN 20.93% O2 700.0C	Press [ESC] to move from run mode to the main menu.

Note: *While in the* OPTS *menu, you may return to run mode at any time by pressing the* [ESC] *key.*

[OPTS] TRIM EXTRA	Make sure OPTS is highlighted and then press [ENTER].

Press [ESC] to return to run mode, or proceed to the next section to continue programming the OPTS menu.

3.9.2a Air Offset Calibration

TST [AIR] GAS RNG	Press [SPACE] to select AIR and then press [ENTER].
AIR 20.93%O2 xxx.xC	Press [ENTER] to accept the new offset value and [BACKSPACE] to return to the OPTS menu. To abort, just press [BACKSPACE] to return to the OPTS menu.

Note: Refer to “Calibration” on page 37 *for a detailed description of the calibration procedures.*

Press [ESC] to return to run mode, or proceed to the next section to continue programming the OPTS menu.

3.9.2b Gas Measurement Calibration

TST AIR [GAS] RNG	Press [SPACE] to select GAS and then press [ENTER].
GAS [x.xx]%O2 xxx.xC	Adjust the O2 value with the [+] and [-] keys. Press [ENTER] to accept the new value and [BACKSPACE] to return to the OPTS menu. To abort, just press [BACKSPACE] to return to the OPTS menu.

Press [ESC] to return to run mode, or proceed to the next section to continue programming the OPTS menu.

3.9.2c Set Oxygen Range

TST AIR GAS [RNG]	Press [SPACE] to select RNG and then press [ENTER].
[O2_RNG] TEMP_RNG	Make sure O2_RNG is selected and then press [ENTER].
5% [10%] 25%	Press [SPACE] to select the desired oxygen range and press [ENTER]. Press [BACKSPACE] to return to the RNG menu.

3.9.3 TRIM Menu

Use the following procedure to move through the TRIM menu.

RUN 20.93%O2 700.0C	Press [ESC] to move from run mode to the *User Program*.

Note: While in the TRIM *menu, you may return to run mode at any time by pressing the* [ESC] *key.*

OPTS [TRIM] EXTRA	Press [SPACE] to select TRIM and then press [ENTER].

3.9.3a Trim Oxygen Output

[TRIM_O2] TRIM_TEMP	Make sure TRIM_O2 is highlighted and press [ENTER].

Note: For the TRIM_O2 *function, always adjust the* 4 mA *setting before the* 20 mA *setting. This will ensure that the instrument operates at optimum accuracy.*

TRIM_O2 mA: [4] 20	Make sure “4” is highlighted and then press [ENTER].
4mA_O2 [xxx] ADJUST	Using [+] and [-], adjust the value to obtain an output signal of 4 mA. Press [ENTER] to accept the new value. Press [BACKSPACE] to back up one menu level.
TRIM_O2 mA: 4 [20]	Press [SPACE] to select “20” and then press [ENTER].
20mA_O2 [xxx] ADJUST	Using [+] and [-], adjust the value to obtain an output signal of 20 mA. Press [ENTER] to accept the new value. Press [BACKSPACE] twice to return to the TRIM menu.

Press [ESC] to return to run mode, or proceed to the next section to continue programming the TRIM menu.

3.9.4 EXTRA Menu

Use the following procedure to move through the EXTRA menu.

RUN 20.93%O2 700.0C	Press [ESC] to move from run mode to the *User Program*.

Note: *While in the* EXTRA *menu, you may return to run mode at any time by pressing the* [ESC] *key.*

OPTS TRIM [EXTRA]	Press [SPACE] to select EXTRA and then press [ENTER].

3.9.4a Selecting Terminal Type

[COM] ERR PID FRZ RESP OFST	Make sure COM is selected and then press [ENTER].

[TTY] ANSI	Press [SPACE] to select the desired option and then press [ENTER]. To return to the EXTRA menu, press [BACKSPACE].

Note: *Select TTY to interface the FGA 311 with a Teletype terminal, or select ANSI to use a computer terminal that communicates via the standard ASCII character set. For most modern personal computers, select the ANSI option.*

Press [ESC] to return to run mode, or proceed to the next section to continue programming the EXTRA menu.

3.9.4b Error Handling Set Up

IMPORTANT: *It is recommended to consult the factory for assistance if you choose to use the error handling options.*

COM [ERR] PID FRZ RESP OFST	Press [SPACE] to select ERR and then press [ENTER].

This sub-menu permits set up of the responses of the FGA 311 to various error situations. The following error states may be configured via this menu:

- ER1: the Sensor Failure! error message.
- ER2: the Warning: Warming Up! error message.
- ER3: the Open Thermocouple! error message.
- ER4: the Heater Failure! error message.

When all of the desired error handling options have been set, press [ESC] to return to run mode, or proceed to the next section to continue programming the EXTRA menu.

Proceed to the desired section(s) now to set any or all of the available error handling functions.

ER1: the Sensor Failure! error message

[ER1] ER2 ER3 ER4	Make sure ER1 is highlighted and then press [ENTER].

Proceed to either the *"Disable ER1"* or *"Set ER1"* prompt.

[ER1-OFF] ER1-SET [Disable ER1]	To disable ER1, make sure ER1-OFF is highlighted and then press [ENTER]. Press [BACKSPACE] to back up one menu level.
ER1-OFF [ER1-SET] [SET ER1]	To set ER1, press [SPACE] to select ER1_SET and press [ENTER].
ER1 [xx.x] mA	Enter the desired value and press [ENTER]. Press [BACKSPACE] to back up one menu level.

3.9.4b Error Handling Set Up (cont.)

ER2: **the Warning: Warming Up! error message**

ER1 [ER2] ER3 ER4	Press [SPACE] to select ER2 and then press [ENTER].

Proceed to either the *"Disable ER2"* or *"Set ER2"* prompt.

[ER2-OFF] ER2-SET [Disable ER2]	To disable ER2, make sure ER2-OFF is highlighted and then press [ENTER]. Press [BACKSPACE] to back up one menu level.
ER2-OFF [ER2-SET] [SET ER2]	To set ER2, press [SPACE] to select ER2_SET and press [ENTER].
ER2 [xx.x] mA	Enter the desired value and press [ENTER]. Press [BACKSPACE] to back up one menu level.

ER3: **the Open Thermocouple! error message**

ER1 ER2 [ER3] ER4	Press [SPACE] to select ER3 and then press [ENTER].

Proceed to either the *"Disable ER3"* or *"Set ER3"* prompt.

[ER3-OFF] ER3-SET [Disable ER3]	To disable ER3, make sure ER3-OFF is highlighted and then press [ENTER]. Press [BACKSPACE] to back up one menu level.
ER3-OFF [ER3-SET] [SET ER3]	To set ER3, press [SPACE] to select ER3_SET and press [ENTER].
ER3 [xx.x] mA	Enter the desired value and press [ENTER]. Press [BACKSPACE] to back up one menu level.

3.9.4b Error Handling Set Up (cont.)

ER4: **the Heater Failure! error message**

ER1 ER2 ER3 [ER4]	Press [SPACE] to select ER4 and then press [ENTER].

Proceed to either the *“Disable ER4”* or *“Set ER4”* prompt.

[ER4-OFF] ER4-SET [Disable ER4]	To disable ER4, make sure ER4-OFF is highlighted and then press [ENTER]. Press [BACKSPACE] to back up one menu level.
ER4-OFF [ER4-SET] [SET ER4]	To set ER4, press [SPACE] to select ER4_SET and press [ENTER].
ER4 [xx.x] mA	Enter the desired value and press [ENTER]. Press [BACKSPACE] to back up one menu level.

3.9.4c Set Up Heater Control

Although the default values for the P and I parameters of the FGA 311 PID heater control circuit are suitable for most applications, it may sometimes be necessary to fine-tune these parameters. Refer to *"The Heater Control Circuit" on page 5* for a discussion of the PID circuit. If an adjustment is indicated, proceed as follows:

IMPORTANT: *Always consult the factory before changing the P or I values.*

COM ERR [PID] FRZ RESP OFST	Press [SPACE] to select PID and then press [ENTER].

Proceed to the appropriate section to set the desired parameter.

SET: **specify the temperature set point (normally 700°C)**

[SET] P I O DEFAULT	Make sure SET is highlighted and then press [ENTER].
SET [xxx] Degrees C	Enter the desired set point value and press [ENTER].

Press [ESC] to return to run mode, or proceed to the next section to continue programming the PID sub-menu.

P: **set the proportional band value**

SET [P] I O DEFAULT	Press [SPACE] to select "P" and then press [ENTER].
P [xxx] Degrees C	Enter the desired proportional band value and press [ENTER].

Press [ESC] to return to run mode, or proceed to the next section to continue programming the PID sub-menu.

3.9.4c Set Up Heater Control (cont.)

I: set the integration time value

SET P [I] O DEFAULT	Press [SPACE] to select "I" and then press [ENTER].
I [xxx] Seconds	Enter the desired integration time value and press [ENTER].

Press [ESC] to return to run mode, or proceed to the next section to continue programming the PID sub-menu.

O: set the overheat value

SET P I [O] DEFAULT	Press [SPACE] to select "O" and then press [ENTER].
P [xxx] Degrees C	Enter the desired overheat value and press [ENTER].

Note: The overheat value should be set to the highest process temperature (acceptable values are 600 – 1200°C). The default value is 820°C.

Press [ESC] to return to run mode, or proceed to the next section to continue programming the PID sub-menu.

DEFAULT: restore the factory default SET, P, I and O values

SET P I O [DEFAULT]	To restore the default values, press [SPACE] to select DEFAULT and press [ENTER].

Press [ESC] to return to run mode, or proceed to the next section to continue programming the EXTRA menu.

3.9.4d Freeze a Reading

In some situations, it may be helpful to freeze an output reading for viewing at a more convenient time. To accomplish this, perform the following steps:

COM ERR PID [FRZ] RESP OFST	Press [SPACE] to select “FRZ” and then press [ENTER].
[FREEZE] UNFREEZE	Press [SPACE] to select the desired menu choice and press [ENTER]. Press [BACKSPACE] to back up one menu level.

Press [ESC] to return to run mode. If FREEZE was selected above, the output display will constantly show the last good reading, until the UNFREEZE option is selected in this sub-menu.

3.9.4e Setting the Response Time

The response time of the FGA 311 may be adjusted using this sub-menu. A shorter response time will provide by more accurate data by updating the display more frequently, but a longer response time will provide a more stable display that is free from flicker.

COM ERR PID FRZ [RESP] OFST	Press [SPACE] to select RESP and then press [ENTER].
RESP [xx] Seconds	Enter the desired response time (values from 1 to 30 seconds are acceptable) and press [ENTER].

Press [ESC] to return to run mode, or return to a previous section to continue programming the PID sub-menu.

[no content intended for this page]

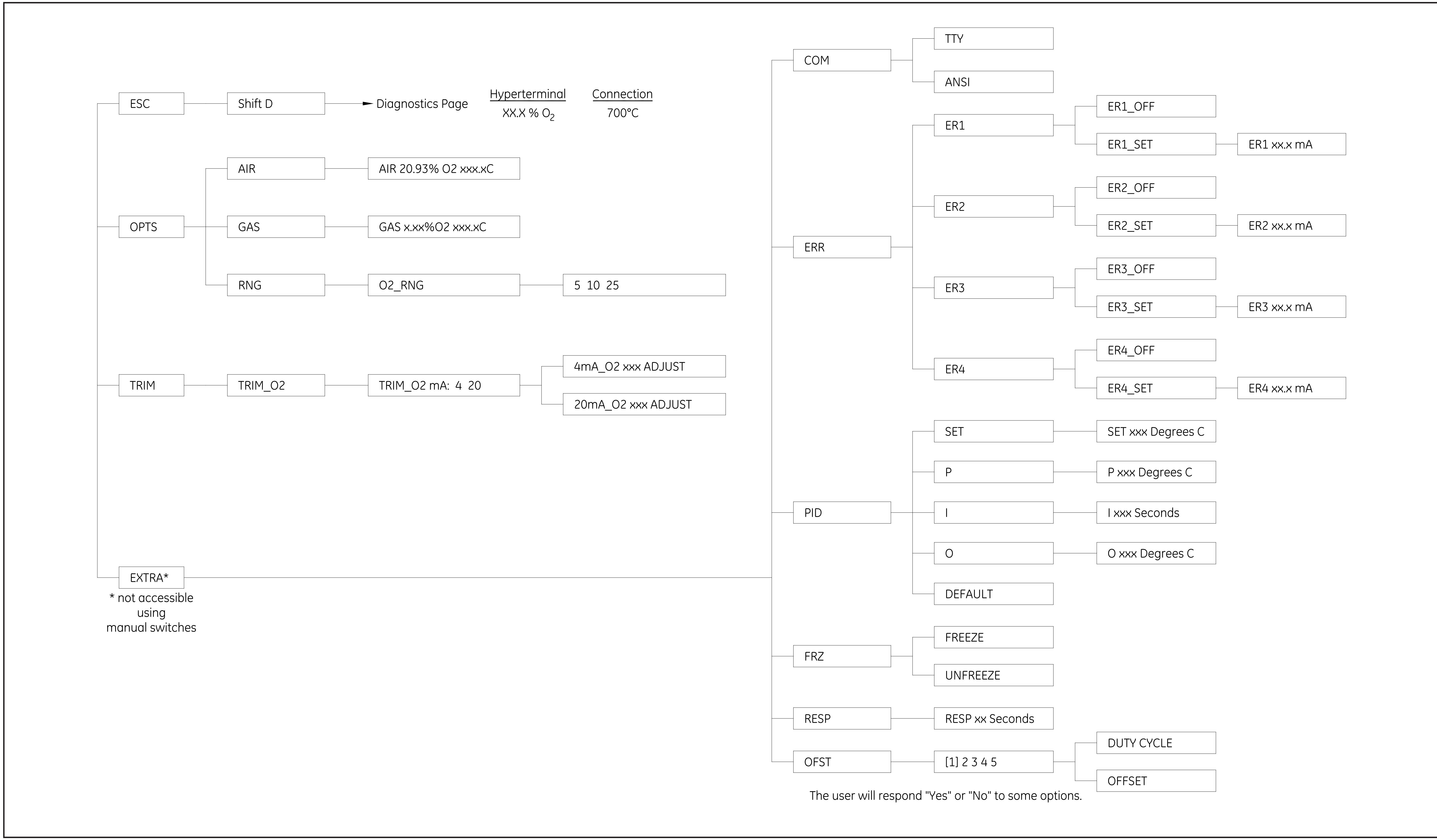


Figure 10: FGA 311 Menu Map

Chapter 4. Calibration

4.1 Introduction

The calibration of the FGA 311 In Situ Flue Gas Oxygen Transmitter should be checked once or twice a week during the first month of operation and every 2-3 months thereafter. Changes in calibration may result from aging of the oxygen sensor, and within limits, temperature calibration adjustments can compensate for such variations.

WARNING! To ensure safe operation of the FGA 311, it must be installed and operated as described in this manual. In addition, be sure to follow all applicable local safety codes and regulations for installing electrical equipment.

IMPORTANT: *This symbol indicates Caution - risk of electric shock:*

4.2 Recommended Calibration Gas

Calibration of the FGA 311 analyzer requires a calibration gas of precisely known composition. The following calibration gas is recommended by GE:

- 5.0% O_2 + 95.0% N_2

Note: *The calibration gas cylinder must be certified as to the exact composition of the gas.*

A 5.0% O_2 calibration gas should produce an oxygen sensor voltage output of 30.0 ± 1.5 mV, at the usual sensor operating temperature of 700°C. The corresponding 4-20 mA analog output will depend on the programmed oxygen range, as shown in *Table 3*.

Table 3: Calibration Gas Current Outputs

O_2 Range	0% O_2	5% O_2	Max.% O_2
5%	4.0 mA	20.0 mA	20.0 mA
10%	4.0 mA	12.0 mA	20.0 mA
25%	4.0 mA	7.2 mA	20.0 mA

Other calibration gases may be used, as long as the oxygen content of the calibration gas is approximately equal to the oxygen percentage in the flue gases to be measured. Of course, the voltage output of the oxygen sensor and the corresponding 4-20 mA analog output would differ from those listed above. Also, the listed values will vary if the oxygen sensor temperature is different from the standard 700°C.

4.3 Measuring the Calibration Response

Refer to *"The Nernst Equation" on page 69*, to calculate the expected oxygen sensor output voltage at whatever O_2% and operating temperature are being used. Calculate the corresponding 4-20 mA analog output signal using *Equation 2*.

$$\text{current (mA)} = 4 + 16 \bullet \left[\frac{\text{oxygen percentage}}{\text{range setting}}\right] \tag{2}$$

For example, if the calibration gas is 2% O_2 and the O_2 range is set to 5%, the mA output should be:

$$4 + 16\,(2/5) = 10.4\text{ mA}$$

Figure 11 on page 39 shows a graphical representation of the procedure. For the same example, pick the applicable range curve (R = 5). Then, move from the chosen oxygen percentage (2.0) on the horizontal axis up to the range curve, and move across to the vertical axis to read the correct analog output (10.4 mA).

To monitor the analyzer's response to the calibration gas, remove the wire from pin 4 (–) or pin 5 (+) on terminal block TB2 and install a digital ammeter between the removed wire and the pin. The current should measure within ±0.3 mA of the 5% O_2 readings listed in *Table 3 on page 37*. Alternatively, the oxygen sensor voltage output may be measured directly by connecting a digital voltmeter across pins 3 (+) and 4 (–) of terminal block J2.

4.4 The Calibration Gas System

The calibration gas should be introduced to the FGA 311 by a system similar to the one shown in *Figure 7 on page 16*. The calibration port plug that is supplied with the FGA 311 must be removed and a temporary connection made, to calibrate the oxygen sensor. However, if a permanent connection is preferred, it should be as short as possible and it should include an isolation valve next to the calibration gas port on the analyzer.

IMPORTANT: *The reference air supply to the FGA 311 must be maintained at its normal flow rate throughout the calibration procedure.*

To accurately calibrate the FGA 311, a calibration gas flow rate of approximately 1000 cc/min (2.1 SCFH) is required. Flow rates lower than this may result in unstable readings, and higher flow rates may cause excessive cooling of the oxygen sensor.

CAUTION! Do not use a calibration gas flow rate higher than 2000 cc/min (4.2 SCFH). Such flow rates will cool the oxygen sensor and lead to inaccurate readings or even cause damage to the sensor.

4.4 The Calibration Gas System (cont.)

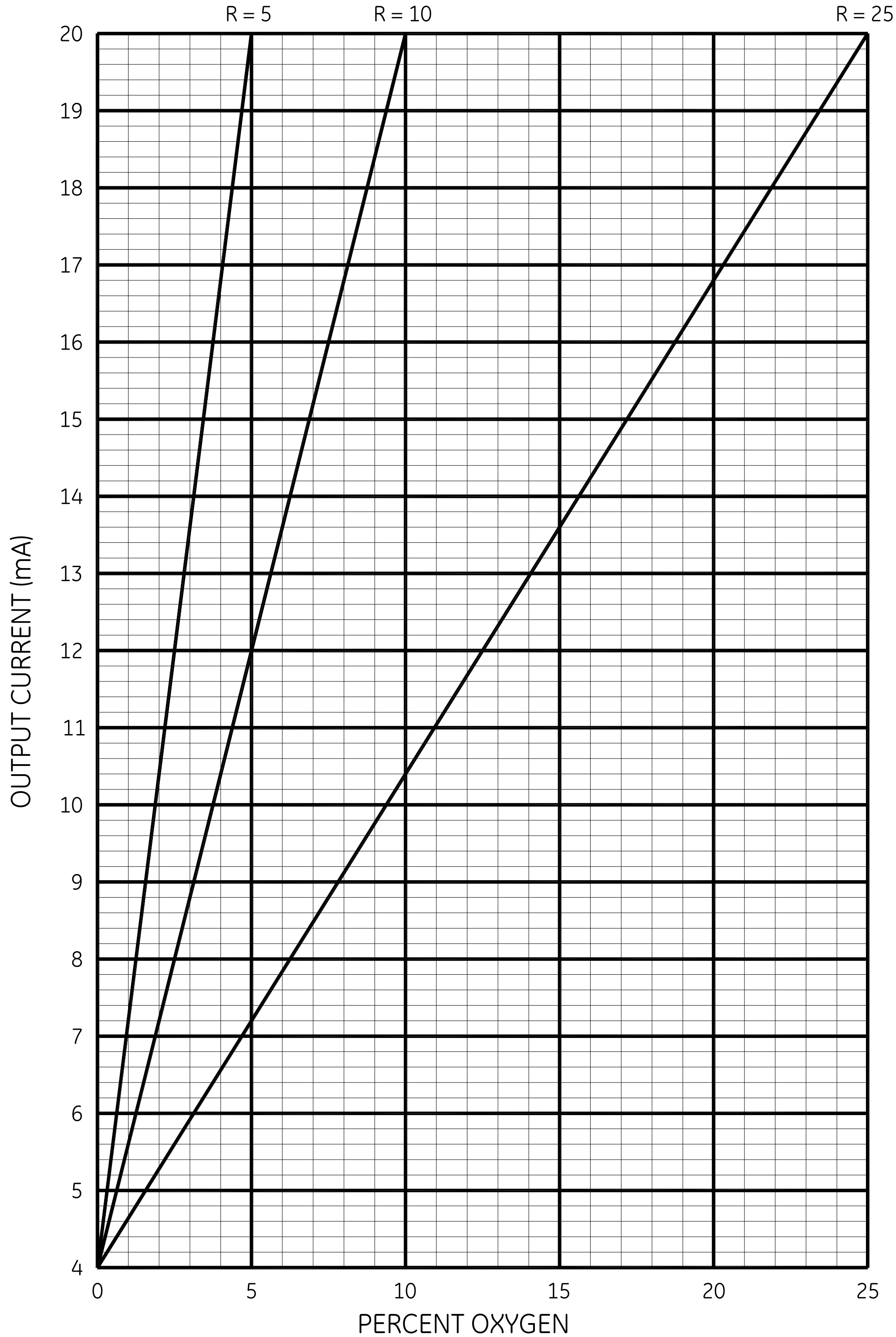


Figure 11: Oxygen Sensor Calibration Output

4.5 Calibrating the Oxygen Sensor

To calibrate the FGA 311 oxygen sensor, either of the two programming methods described in *"Operation and Programming" on page 17* (manual switches or a PC connection), may be used. Proceed to the appropriate section for the chosen programming method.

Note: *Make sure that the analyzer has been powered ON and has been allowed to warm up for at least one hour before attempting to calibrate the oxygen sensor.*

4.5.1 Calibrating with the Manual Switches

To calibrate the analyzer with the manual switches located on the FGA 311 circuit board, complete the following steps:

Note: *See "Operation and Programming" on page 17 for general information on using the manual switches.*

1. For optional AIR calibration, establish a flow of atmospheric air into the calibration port for at least five minutes at a flow rate of 1000 cc/min (2 SCFH). This air may be obtained by tapping a line off the reference air source. See *Figure 7 on page 16* for a suggested piping arrangement.

2. Perform optional AIR calibration as follows:

- **a.** Set Mode Switch S1 to position 1 (AIR) and wait for the output reading to stabilize at 20.93%.
- **b.** Push CAL Switch S3 and hold until the green range LED's begin to blink (about five seconds).
- **c.** When the green LED stops blinking (about 30 seconds), the calibration is complete. Press CAL Switch S3 and hold for 5 seconds (until the LED's stop blinking) to EXIT programming mode.
- **d.** Verify that the output reading of the analyzer indicates an oxygen level of 20.93% ± 0.1%.

3. Stop the flow of atmospheric air to the calibration port and begin the flow of the chosen calibration gas. Allow this flow to continue for at least five minutes at a flow rate of 1000 cc/min (2.1 SCFH).

4. Perform the GAS calibration as follows:

- **a.** Set Mode Switch S1 to position 2 (GAS).
- **b.** Push CAL Switch S3 and hold until the green range LED begins to blink (about five seconds).
- **c.** Using ADJ Switch S2, adjust the output reading of the analyzer to indicate the correct oxygen percentage within 0.1%, as described earlier in this chapter.

Note: *After each adjustment, wait for the reading to stabilize before performing any additional adjustments.*

- **d.** Press CAL Switch S3 and hold for 5 seconds (until the LED's stop blinking) to EXIT programming mode.

5. Stop the flow of calibration gas to the unit.

The FGA 311 In Situ Flue Gas Oxygen Transmitter is now properly calibrated and ready for use.

4.5.2 Calibrating with a PC Connection

To calibrate the analyzer with a personal computer (PC) connected via the RS232 port, complete the following steps:

Note: *See “Operation and Programming” on page 17 for general information on using the PC connection.*

1. Establish a flow of atmospheric air into the calibration port for at least five minutes at a flow rate of 1000 cc/min (2 SCFH). This air may be obtained by tapping a line off the reference air source. See *Figure 7 on page 16* for a suggested piping arrangement.

2. Perform optional AIR calibration as follows:

- **a.** Press [ESC] to move from run mode to the *User Program*.
- **b.** Using the [SPACE] key if necessary, make sure OPTS is highlighted and then press [ENTER].
- **c.** Use the [SPACE] key to select the AIR option, and then press [ENTER]. Wait for the reading to stabilize.
- **d.** Press [ENTER] to accept the new offset value.
- **e.** Press [ESC] to leave the *User Program* and return to run mode.

3. Stop the flow of atmospheric air to the calibration port and begin the flow of the chosen calibration gas. Allow this flow to continue for at least five minutes at a flow rate of 1000 cc/min (2.1 SCFH).

4. Perform the GAS calibration as follows:

- **a.** Press [ESC] to move from run mode to the *User Program*.
- **b.** Using the [SPACE] key if necessary, make sure OPTS is highlighted and then press [ENTER].
- **c.** Use the [SPACE] key to select the GAS option, and then press [ENTER].
- **d.** Use the [+] and [–] keys to adjust the O2 value to correspond with the known oxygen content of the calibration gas.

Note: *After each adjustment, wait for the reading to stabilize before performing any additional adjustments.*

- **e.** Press [ENTER] to accept the new oxygen value.
- **f.** Press [ESC] to leave the *User Program* and return to run mode.

5. Stop the flow of calibration gas to the unit.

The FGA 311 In Situ Flue Gas Oxygen Transmitter is now properly calibrated and ready for use.

4.6 Resume Operation

If a temporary calibration gas connection was made, disconnect the calibration gas line and reinstall the plug on the calibration gas port. If a permanent calibration gas connection was installed, close the shut-off valve. Then, normal operation of the analyzer may be resumed.

Chapter 5. Troubleshooting

5.1 Introduction

The FGA 311 In Situ Flue Gas Oxygen Transmitter has been designed to overcome most of the problems commonly associated with monitoring flue gases. However, because of the corrosive and extreme conditions under which the instrument must operate, some difficulties may still be encountered. Procedures for resolving such situations are discussed in this chapter. If the required information can not be found in this chapter, contact GE for assistance.

Two modes of error reporting have been built into the FGA 311 software:

- a fault indicator that is mounted on the printed circuit board
- an error message system that is accessible via the RS232 interface

Additional troubleshooting clues may be found by observing any unusual readings from the 4-20 mA output on terminal block TB2.

WARNING! To ensure safe operation of the FGA 311, the instrument must be installed and operated as described in this manual. In addition, be sure to follow all applicable local safety codes and regulations for installing electrical equipment.

WARNING! The procedures in this manual should be performed only by trained service personnel.

5.2 Troubleshooting Guide

The most commonly encountered indicators of an operational problem with the FGA 311 are listed in Table 4. Refer to this table as the initial source of information regarding a specific problem. The table will indicate the location of a more detailed discussion of the problem and its solution.

IMPORTANT: *This symbol indicates Caution - risk of electric shock:*

When working within the FGA 311 enclosure, be aware that full line voltage is present at terminal block TB1 on the printed circuit board, if the power is still applied to the unit. Be sure to observe any warnings noted in the individual troubleshooting sections of this chapter. Refer to *"Service and Maintenance" on page 55* for the location or replacement of any components mentioned during the troubleshooting procedure.

Table 4: Troubleshooting Guide

Problem Description	Possible Cause(s)	Go To:
Temperature Problems		
ER2: "Warning: Warming Up!" replaces "RUN" on the PC and the red fault LED flashes two times on the FGA 311	1. insufficient warm-up time allowed 2. defective heater or thermocouple 3. defective wiring or PC board	page 47
ER3: "Open Thermocouple!" replaces "RUN" on the PC and the red fault LED flashes three times on the FGA 311	1. defective thermocouple 2. defective wiring or PC board	page 48
ER4: "Heater Failure!" replaces "RUN" on the PC and the red fault LED flashes four times on the FGA 311	1. defective heater 2. defective wiring or PC board	page 49
Output Problems		
no response from the FGA 311 (4-20 mA, RS232 and PC Board LEDs show no output)	1. no power to unit 2. blown fuse 3. defective PC board	page 50
no RS232 output, but the PC board LEDs and the 4-20 mA output are active	1. defective wiring 2. defective EPROM	page 51
Oxygen Reading Problems		
ER1: "Sensor Failure!" replaces "RUN" on the PC and the red fault LED glows constantly on the FGA 311	1. defective oxygen sensor 2. wiring problem 3. defective PC board	page 52
percent oxygen always reads 20.93%	1. air leak in plumbing 2. defective wiring or PC board	page 53
percent oxygen is stuck on same reading for more than 15 minutes	1. display left in FREEZE mode 2. clogged filter	page 53
oxygen reading is lower than expected	1. combustibles in sample gas	page 54
oxygen reading is higher than expected	1. leak in plumbing	page 54

5.3 Diagnostics Page

One of the most important troubleshooting tools is the diagnostics page (see Figure 12). It will show not only the error messages, but also several parameters that will enable the factory representative to evaluate the performance of the analyzer in situ.

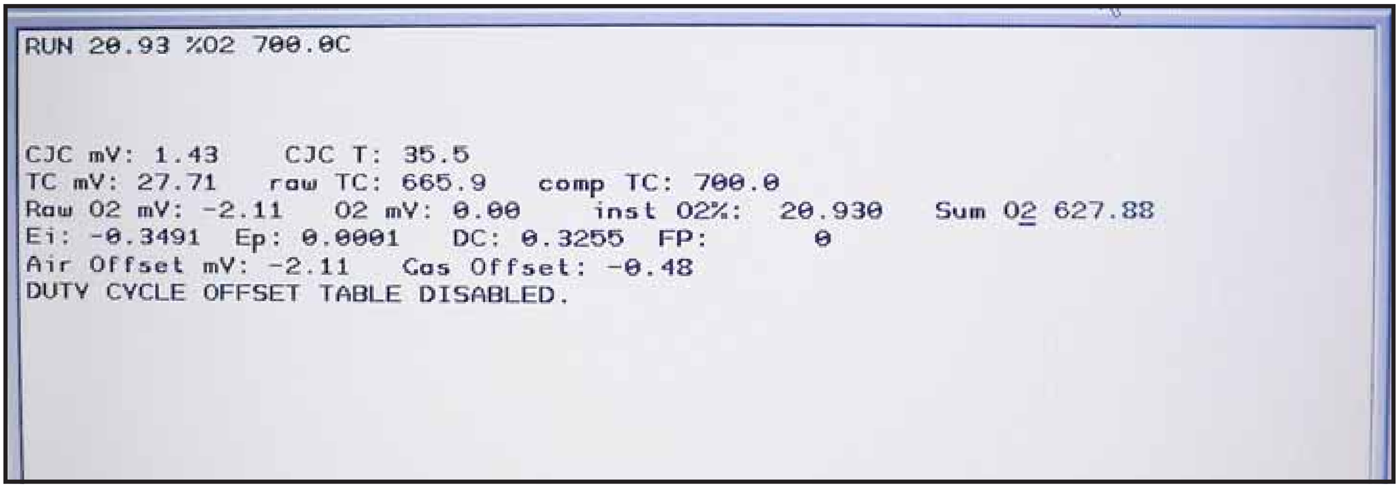
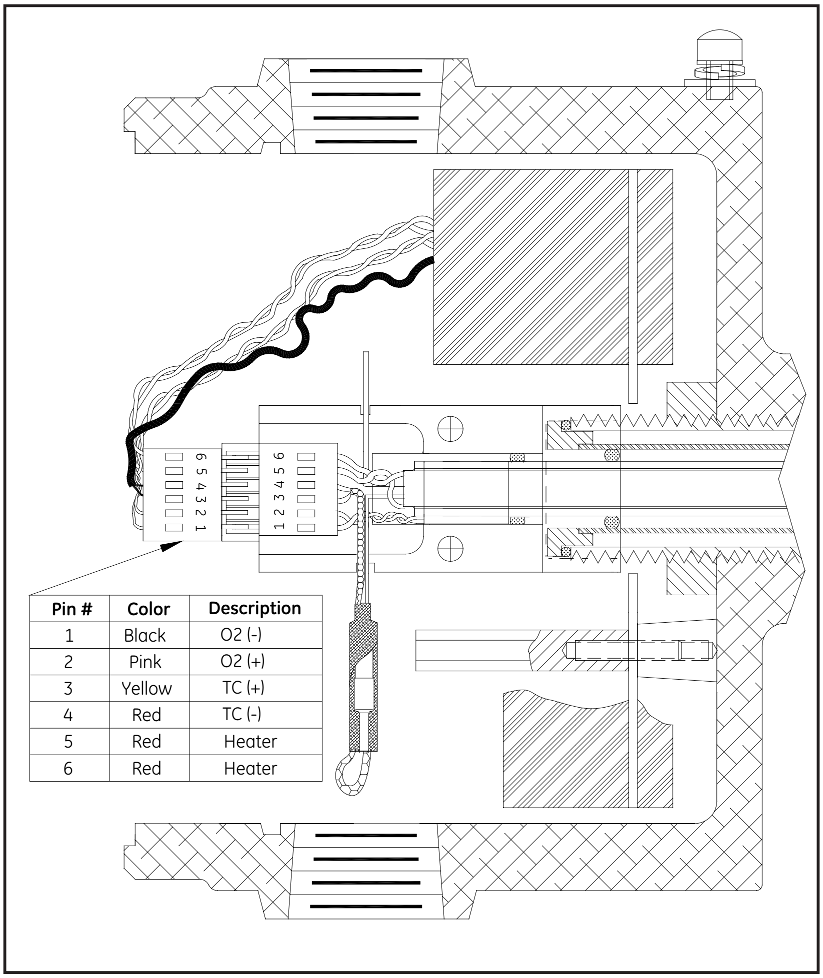


Figure 12: Diagnostics Page for a Normal FGA 311

5.4 Sensor/Heater Wiring

As an aid in following the troubleshooting procedures described in this chapter, the wiring connections for the FGA 311 sensor/heater sub-assembly are shown in *Figure 13*.



Pin #	Color	Description
1	Black	O2 (-)
2	Pink	O2 (+)
3	Yellow	TC (+)
4	Red	TC (-)
5	Red	Heater
6	Red	Heater

Figure 13: Sensor/Heater Connections

5.5 Temperature Problems

If the FGA 311 has difficulty in achieving or maintaining the normal operating temperature of 700 °C, the problem will be indicated in two ways:

- the red fault LED located on the printed circuit board will begin to flash
- if the FGA 311 RS232 interface is connected to a computer, the standard measurement screen will show one of the built-in error messages.

Proceed to the appropriate sub-section for detailed information on specific temperature problems.

5.5.1 ER2 Error Code

When the ER2 error code is generated, the red fault LED on the printed circuit board will begin to flash in groups of two flashes each and the following message screen is sent to the computer via the RS232 interface:

ER2 20.93% O2 700.0C

ER2 replaces RUN on the measurement mode screen.

Although as long as three hours may be required to achieve a stable output, the FGA 311 should reach normal operating temperature in about 30 minutes. When the proper operating temperature has been reached, the ER2 error message is replaced by the normal measurement screen.

Note: The actual Warning: Warming Up! *message only appears on the multi-line diagnostic PC screen.*

If this message is displayed on the screen, complete the following troubleshooting steps:

1. Allow at least thirty minutes for the unit to warm up. If the ER2 error message persists beyond the 30-minute warm-up time, proceed to step 2.

2. Usually, a defective heater or thermocouple will generate its own error message. However, it is helpful to verify the integrity of these components now by completing the following steps:

WARNING! Disconnect the main power from the unit and allow at least two hours for the system to cool down before proceeding with the following steps.

- **a.** Pull the connector from the end of the sensor/heater sub-assembly. Using a digital multimeter, measure the resistance between the two heater connections (pins 5 and 6, on the sensor/heater assembly. The reading should be about 160 ohms for a 110 VAC heater or 380 ohms for a 220 VAC heater. If the reading is significantly higher, the heater is defective and the sensor/heater sub-assembly must be replaced (see *“Sensor/Heater Sub-Assembly Replacement” on page 59*).

IMPORTANT: *Do not measure the heater resistance on the loose connector, which contains the wires going to the PC board.*

- **b.** If the heater appears to be good, reinstall the connector on the end of the sensor/heater sub-assembly and proceed to step 3.

3. If sufficient warm-up time has been allowed and the heater is good, then the problem is the result of faulty wiring or a defective printed circuit board. Proceed as follows:

- **a.** Refer to *“Installation” on page 7*, including the wiring diagram in *Figure 6 on page 13*, and to *Figure 13 on page 46*. Make sure that all of the wires have been connected to the proper terminal blocks. Also, carefully inspect the wiring for shorts and be certain that all of the cable connectors are properly seated in their terminal blocks. Lastly, verify that each individual lead is still firmly seated in its connector.
- **b.** If no wiring problems were discovered in the step above, the circuit board is defective and it must be replaced (see *“Printed Circuit Board Replacement” on page 60*).

5.5.2 ER3 Error Code

When the ER3 error code is generated, the red fault LED on the printed circuit board will begin to flash in groups of three flashes each, and the following message screen will be sent to the PC via the RS232 interface:

ER3 20.93% O2 700.0C

ER3 replaces RUN on the measurement mode screen.

Note: The actual Open Thermocouple *message will appear on the multi-line diagnostic PC screen.*

If this message is displayed on the screen, complete the following troubleshooting steps:

WARNING! **Disconnect the main power from the unit and allow at least two hours for the system to cool down before proceeding with the following steps.**

1. Pull the connector from the end of the sensor/heater sub-assembly. Using a digital multimeter, measure the resistance between the two thermocouple leads (pins 3 and 4, on the sensor/heater assembly). If the reading indicates an open circuit, the thermocouple is defective and the sensor/heater sub-assembly must be replaced (see *"Sensor/Heater Sub-Assembly Replacement" on page 59*). If the thermocouple does not show an open circuit, proceed to step 2.

IMPORTANT: *Do not measure the thermocouple resistance on the loose connector, which contains the wires going to the PC board.*

2. If the thermocouple is good, then the problem is the result of faulty wiring or a defective printed circuit board.

a. Refer to *"Installation" on page 7*, including the wiring diagram in *Figure 6 on page 13*, and to *Figure 13 on page 46*. Make sure that all of the wires have been connected to the proper terminal blocks. Also, carefully inspect the wiring for shorts and be certain that all of the cable connectors are properly seated in their terminal blocks. Lastly, verify that each individual lead is still firmly seated in its connector.

b. If no wiring problems were discovered above, the circuit board is defective and it must be replaced (see *"Printed Circuit Board Replacement" on page 60*).

5.5.3 ER4 Error Code

When the ER4 error code is generated, the red fault LED on the printed circuit board will begin to flash in groups of four flashes each and the following message screen will be sent to the PC via the RS232 interface:

ER4 20.93% O2 700.0C

ER4 replaces RUN on the measurement mode screen.

Note: The actual Heater Failure! *message only appears on the multi-line diagnostic PC screen.*

If this message is displayed on the screen, complete the following troubleshooting steps:

WARNING! **Disconnect the main power from the unit and allow at least two hours for the system to cool down before proceeding with the following steps.**

1. Pull the connector from the end of the sensor/heater sub-assembly. Using a digital multimeter, measure the resistance between the two heater connections (pins 5 and 6, on the sensor/heater sub-assembly). The reading should be about 160 ohms for a 110 VAC heater or 380 ohms for a 220 VAC heater. If the reading is significantly higher than this, the heater is defective and the sensor/heater sub-assembly must be replaced (see *“Sensor/Heater Sub-Assembly Replacement” on page 59*).

IMPORTANT: *Do not measure the thermocouple resistance on the loose connector, which contains the wires going to the PC board.*

2. If the heater appears to be good, reinstall the connector on the end of the sensor/heater sub-assembly. The problem is likely the result of faulty wiring or a defective printed circuit board, and the following steps should be completed.

- **a.** Refer to *“Installation” on page 7*, including the wiring diagram in *Figure 6 on page 13*, and to *Figure 13 on page 46*. Make sure that all of the wires have been connected to the proper terminal blocks. Also, carefully inspect the wiring for shorts and be certain that all of the cable connectors are properly seated in their terminal blocks. Lastly, verify that each individual lead is still firmly seated in its connector.
- **b.** If no wiring problems were discovered in the step above, the circuit board is defective and it must be replaced (see *“Printed Circuit Board Replacement” on page 60*).

5.6 Output Problems

If one or more of the analyzer's outputs is completely non-functional, proceed with the instructions in this section.

5.6.1 All Outputs Inactive

If the analyzer is completely inactive (i.e. there is no RS232 or 4-20 mA signal output and all of the LEDs on the printed circuit board are OFF), there is a power failure in the system. Proceed as follows:

IMPORTANT: *This symbol indicates Caution - risk of electric shock:*

1. Check the input power to the PC board as follows:

- **a.** Remove the plastic cover from the fuse holder.
- **b.** Use a digital AC voltmeter to check the power into the printed circuit board. Place one of the voltmeter leads on the ground terminal inside the FGA 311 enclosure and place the other voltmeter lead on the end of the fuse holder closest to terminal block TB1 on the printed circuit board.
- **c.** The above test point is the direct input line to the printed circuit board, and full line voltage should be present there. If there is no voltage at that point, check the power source, the main disconnect and the connections to terminal block TB1.
- **d.** If there is full line voltage reaching the PC board, proceed to the next step.

2. Check the fuse as follows:

- **a.** Place one of the voltmeter leads on the ground terminal inside the FGA 311 enclosure and place the other voltmeter lead on the end of the fuse holder farthest from terminal block TB1 on the printed circuit board.
- **b.** If full line voltage is not present at the above test point, the fuse is defective and must be replaced (see *"Fuse Replacement" on page 57*).
- **c.** If there is full line voltage at the test point, proceed to the next step.

3. The presence of full line voltage at both ends of the fuse holder indicates that the proper power is reaching the printed circuit board. Therefore, the printed circuit board is defective and must be replaced (see *"Printed Circuit Board Replacement" on page 60*).

5.6.2 No RS232 Output

If the analyzer is operating normally, but the RS232 interface is not functioning, proceed with the following steps:

1. Carefully inspect the RS232 cable connections within the FGA 311 enclosure. Make sure there are no shorts caused by faulty wiring at the connector to terminal block TB2 on the printed circuit board. Also, verify that positive contact is being made by the leads to pins 1-3 of this terminal block. If these connections are secure, proceed to the next step.

2. At the PC end of the RS232 cable, make sure that the DB9 connector is securely installed on the serial port of the computer. Refer to the computer's documentation and the FGA 311 RS232 interface parameters (see *"RS232 Serial Port Settings" on page 24*). If the RS232 interface has been properly established, in accordance with these requirements, proceed to the next step.

Note: *Frequently, reversing leads 2 and 3 of the RS232 connection on terminal block TB2 will solve this type of problem.*

3. The EPROM is defective and must be replaced (see *"EPROM Replacement" on page 62*).

5.7 Oxygen Reading Problems

The generation of inaccurate oxygen readings by the FGA 311 is indicated in two ways:

- the red fault LED located on the printed circuit board will begin to flash and the ER1 error code is generated on a PC that is connected via the RS232 serial port.
- unusual or unexpected oxygen percentages will be read at the 4-20 mA output terminals (pins 4-5) on terminal block TB2.

Proceed to the appropriate sub-section for detailed information on specific oxygen reading problems.

Note: *The most common reason that the O_2 reading is not correct (high or low) is because the calibration gas has not fully displaced the process gas from the sensor area. Increase the calibration flow from 1000 cc/min to 1500 cc/min. If the reading is closer to the span value, continue to increase the flow. If the reading remains unchanged, look for another reason.*

5.7.1 ER1 Error Code

When the ER1 error code is generated, the red fault LED on the PC board flashes in groups of one flash each and the following message screen is sent to the PC via the RS232 interface:

ER1 20.93% O2 700.0C

ER1 replaces RUN on the measurement mode screen.

Note: *The actual* Sensor Failure! *message only appears on the multi-line diagnostic PC screen.*

If this message is displayed on the screen, complete the following troubleshooting steps:

WARNING! **Disconnect the main power from the unit and allow at least two hours for the system to cool down before proceeding with the following steps.**

1. Check the oxygen sensor as follows:

a. Remove the electrical connector from the end of the sensor/heater sub-assembly (see *Figure 13 on page 46*).

b. Using a digital multimeter, measure the resistance between the oxygen sensor connections (pins 1 and 2, on the sensor/heater sub-assembly connector).

IMPORTANT: *Do not measure the oxygen sensor resistance on the loose connector, which contains the wires going to the PC board.*

c. If the reading indicates an open circuit, the oxygen sensor is defective and the entire sensor/heater sub-assembly must be replaced (see *"Sensor/Heater Sub-Assembly Replacement" on page 59*).

d. If the oxygen sensor is good, reinstall the connector on the end of the sensor/heater sub-assembly and proceed to step 2.

2. Check the wiring and the printed circuit board as follows:

a. Carefully inspect the connector at terminal block J2 on the printed circuit board for shorts and/or wires that are not securely seated in the connector. Pay particular attention to the oxygen sensor leads at pins 3-4 of this connector.

b. Carefully inspect the connector on the end of the sensor/heater sub-assembly for shorts and/or wires that are not securely seated in the connector. Pay particular attention to the oxygen sensor leads at pins 1-2 of this connector.

c. If no wiring problems were discovered in the step above, the circuit board is defective and must be replaced (see *"Printed Circuit Board Replacement" on page 60*).

5.7.2 Oxygen Percentage Always Reads 20.93

This condition is somewhat unusual, and it is probably caused by a leak in the plumbing, a defect in the printed circuit board, or defective wiring. To isolate the problem, complete the following steps:

1. A leak in the plumbing may cause the reference air to become contaminated with the process flue gases. When the zirconium oxide oxygen sensor has the same oxygen content on both sides of the cell, its output will be 0.0 mV, which will generate a 4-20 mA signal that converts to 20.93% oxygen. Find and correct any plumbing leaks that could cause the above contamination to occur. If the problem persists, proceed to the next step.
2. Check for shorts in the oxygen sensor wiring at pins 1 and 2 on the sensor/heater sub-assembly connector and at pins 3 and 4 of terminal block J2 on the printed circuit board.
3. If no plumbing leaks or oxygen sensor wiring shorts were found, remove the connector from the end of the sensor/heater sub-assembly. Using a digital voltmeter, measure the voltage across pins 1 (-) and 2 (+) on the sensor/heater sub-assembly (not the loose connector). If this voltage is 0.0 mV, the 20.93% oxygen reading is valid. If some non-zero voltage is read, the printed circuit board is defective and must be replaced (see *"Printed Circuit Board Replacement" on page 60*).

5.7.3 Oxygen Percentage Unchanged for more than 15 Minutes

It is possible that the flue gas composition really is this stable. However, if such is not the case, there are two likely causes for this problem:

1. The analyzer may have accidentally been left in FREEZE mode. Refer to *"Operation and Programming" on page 17*, and select the UNFREEZE option from the EXTRA menu. If the unit was not in FREEZE mode, proceed to the next step.
2. The porous filter on the end of the probe assembly may have become clogged. If this is the case, the probe tip will have to be cleaned or replaced (see *"Probe Tip Replacement" on page 55*).

5.7.4 Oxygen Reading Lower Than Expected

The zirconium oxide oxygen sensor will respond to combustibles such as CO, H_2 or other hydrocarbons in the sample gases by generating several millivolts of additional voltage output. Although the FGA 311 will accurately process this information, the resulting oxygen reading will be lower than expected. Some possible sources of such contamination are:

- oil or grease in the plumbing system
- pipe thread compound on the fittings
- oil or grease on the oxygen sensor due to handling the sensor with bare hands
- excess fuel in the burner.

Resolve the problem be finding and eliminating the source of the contaminating combustibles.

5.7.5 Oxygen Reading Higher Than Expected

The likely cause of an oxygen reading that is higher than expected is a gas leak that permits the reference air to become contaminated with the process flue gases. This contamination will lower the millivolt output of the zirconium oxide oxygen sensor, and the 4-20 mA output signal will indicate an oxygen percentage that is higher than expected.

Although the FGA 311 will accurately process this information, the result will not reflect the actual oxygen content of the flue gases. To correct the problem, find and correct any plumbing leaks that could cause the above contamination to occur.

Chapter 6. Service and Maintenance

6.1 Introduction

Although the FGA 311 has been engineered for long, trouble-free service, some components may require occasional replacement. The FGA 311 has been designed for quick and easy field replacement of these components, when it does become necessary.

6.2 Probe Tip Replacement

The only field-replaceable external component of the FGA 311 is the probe tip. The probe tip may become clogged or cracked over time and require cleaning or replacement. If this is the case, refer to *Figure 14* and complete the following steps:

1. Power down the FGA 311 and allow approximately two hours for it to cool down to ambient temperature.

WARNING! **Disconnect the main power from the unit and allow at least two hours for the system to cool down before proceeding with the following steps.**

2. Disconnect all electrical and mechanical lines from the analyzer.

3. Remove the unit from the flue. See *"Installation" on page 7* for details on mounting the analyzer to the flue wall.

4. Unthread the existing probe tip from the end of the probe base.

5. Either clean the existing probe tip or, if it is damaged, obtain a replacement.

IMPORTANT: *Do not use a thread sealant on the probe threads. However, a dry, high-temperature, graphite-based lubricant may be used.*

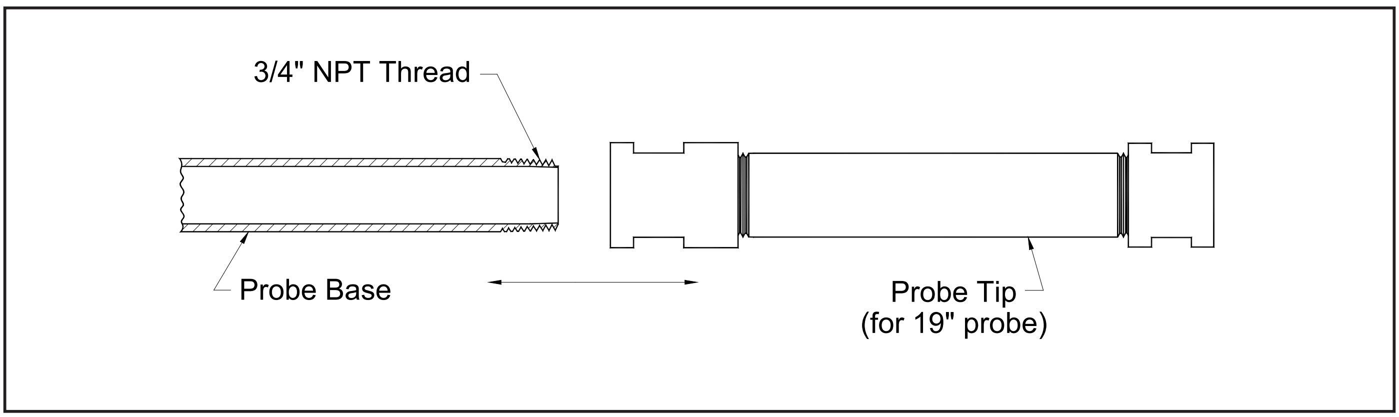


Figure 14: Probe Tip Replacement

6.2 Probe Tip Replacement (cont.)

6. Apply the thread lubricant to the probe threads and securely tighten the probe tip onto the end of the probe base.

7. Reinstall the FGA 311 into the flue wall. See *"Installation" on page 7* for specific instructions.

8. Reconnect all electrical and mechanical lines to the analyzer body.

9. Apply power to the unit and let it heat back up to the normal operating temperature of 700°C. This should take approximately thirty minutes.

Normal operation of the FGA 311 may now be resumed.

6.3 Cover Removal and Reinstallation

All other field-replaceable components are located within the FGA 311 enclosure, and removal of the unit need from the flue stack is not required to service these items. The first step in replacing these parts is to remove the cover from the enclosure. To do so, refer to *Figure 15* and complete the following steps:

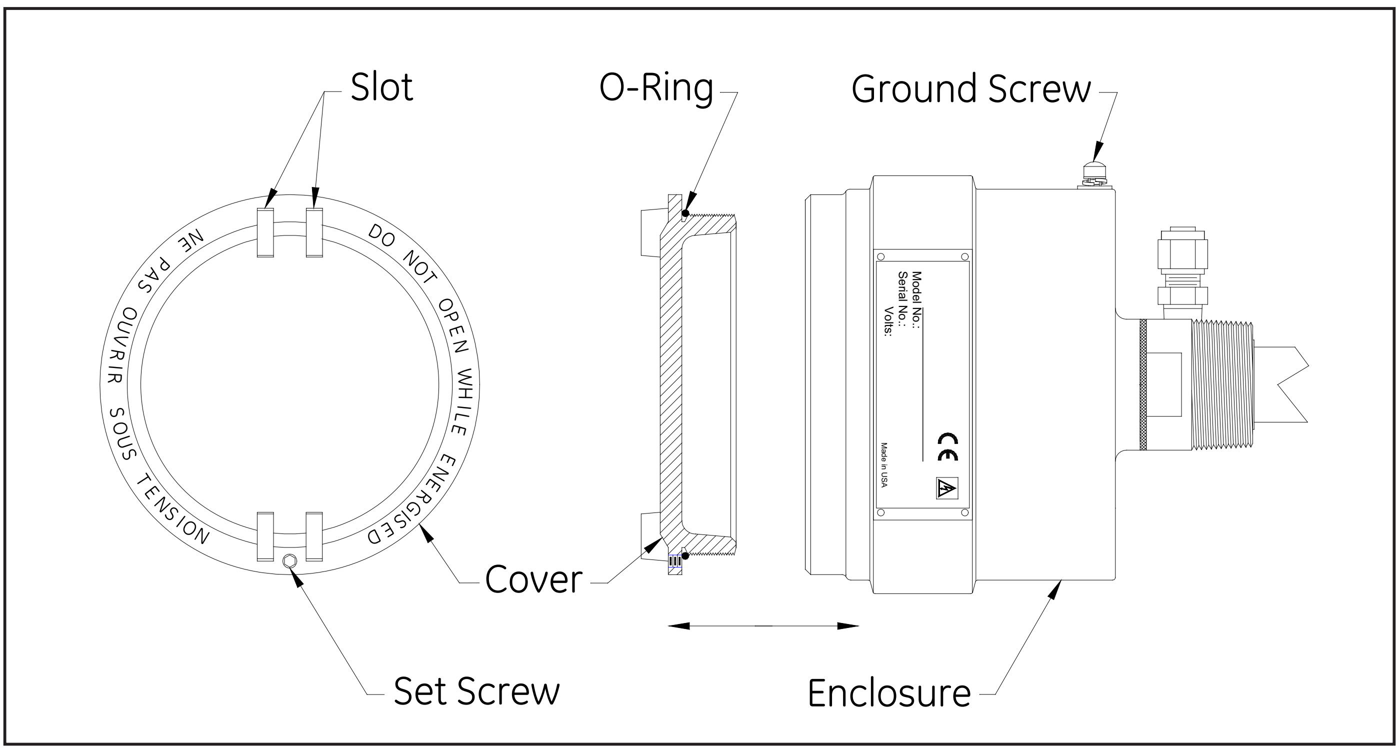


Figure 15: Cover Removal

6.3 Cover Removal and Reinstallation (cont.)

1. Loosen (do not remove) the locking set screw that is located near one of the slots on the cover.

IMPORTANT: *These symbols indicate Caution - dangerously hot surfaces and risk of electric shock, respectively:*

2. Place a large screwdriver or similar tool across the two slots located on the cover. Using the screwdriver as a lever, begin to rotate the cover in a counter-clockwise direction. After the cover has been loosened, continue to unthread it by hand and pull the cover away from the enclosure.

3. Complete whatever maintenance is required within the enclosure, as instructed later in this chapter.

4. Make sure that the o-ring is still in place on the cover, and thread the cover back into the enclosure. Using the large screwdriver across the slots, tighten the cover securely.

5. Lock the cover in place by tightening the set screw located near one of the slots.

The FGA 311 may now be placed back into service.

6.4 Fuse Replacement

To replace the fuse in the FGA 311, refer to *Figure 16 on page 58* and complete the following steps:

1. Disconnect the main power from the analyzer.

WARNING! Disconnect the main power from the unit and allow at least two hours for the system to cool down before proceeding with the following steps.

2. Remove the cover from the enclosure, as described above.

3. Pull the soft plastic protective cover off the fuse holder.

4. Pull the fuse out of its holder and replace it with a new fuse. See *"Specifications" on page 65* for the correct replacement fuse ratings.

5. Reinstall the protective plastic cover over the fuse holder.

6. Reinstall the cover, as described above. Power up the unit and allow it to warm up for at least one hour.

6.4 Fuse Replacement (cont.)

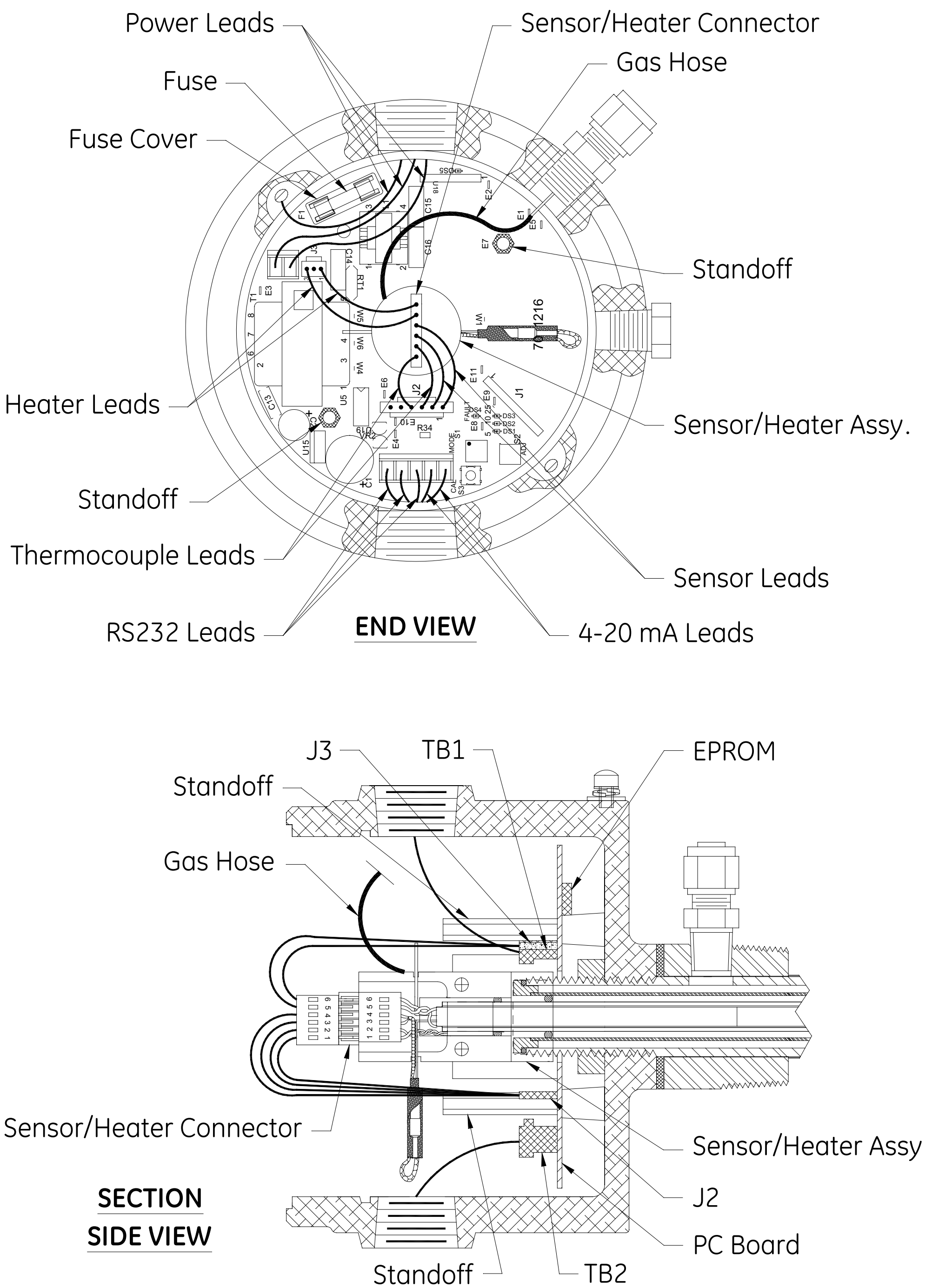


Figure 16: Internal View of Enclosure

6.5 Sensor/Heater Sub-Assembly Replacement

If either the heater, the thermocouple or the oxygen sensor becomes defective, the sensor/heater sub-assembly must be replaced. To do so, refer to *Figure 16 on page 58* and proceed to the next section.

CAUTION! Never disassemble or attempt to repair the sensor/heater sub-assembly in the field. The entire sub-assembly must be replaced as a complete unit.

6.5.1 Removing the Sensor/Heater Sub-Assembly

Remove the defective sensor/heater sub-assembly as follows:

1. Power down the FGA 311 and allow at least two hours for the unit to cool down to ambient temperature. Remove the cover from the enclosure, as described in *"Cover Removal and Reinstallation" on page 56*.

WARNING! Disconnect the main power from the unit and allow at least two hours for the system to cool down before proceeding with the following steps.

2. Pull the 1/8" black calibration gas hose off the calibration gas fitting on the sensor/heater sub-assembly.

3. Pull the 6-wire connector off the end of the sensor/heater sub-assembly.

4. Grasp the black plastic block at the end of the sensor/heater sub-assembly, and turn it counterclockwise until it comes free from the threads in the base of the enclosure.

CAUTION! The exposed ends of the oxygen cell are easily damaged if they strike a hard surface. Also, do not handle the exposed ends of the oxygen cell with bare fingers, as deposits of skin oils and/or salts may seriously impair sensor operation.

5. Carefully, pull the sensor/heater sub-assembly straight out of the enclosure.

Proceed to the next section for instructions on installing the sensor/heater sub-assembly.

6.5.2 Installing the Sensor/Heater Sub-Assembly

Refer to **Figure B-4 in Appendix B**, for an illustration of the sensor/heater sub-assembly. To install the new assembly, refer to *Figure 16 on page 58* and complete the following steps:

1. Carefully, slide the sensor/heater sub-assembly straight into the opening at the base of the enclosure.

CAUTION! The exposed ends of the oxygen cell are easily damaged, if they strike a hard surface. Also, do not handle the exposed ends of the oxygen cell with bare fingers, as deposits of skin oils and/or salts may seriously impair sensor operation.

2. Grasp the black plastic block at the end of the sensor/heater sub-assembly, and screw the assembly into the threads at the base of the enclosure. Proper tightening of the assembly requires that it be turned clockwise until it is hand-tight and then turned an additional 1/4 turn.

3. Attach the 6-wire connector to the end of the sensor/heater sub-assembly.

4. Push the 1/8” black calibration gas hose onto the calibration gas fitting on the sensor/heater sub-assembly.

5. Reinstall the cover on the enclosure, as described in *“Cover Removal and Reinstallation” on page 56*, and power up the FGA 311.

After the unit has heated up to its normal operating temperature of 700°C (about thirty minutes), data collection may be resumed.

6.6 Printed Circuit Board Replacement

If the printed circuit board becomes defective, replace it by referring to *Figure 16 on page 58* and completing the steps in the following sections

6.6.1 Removing the Printed Circuit Board

Remove the defective printed circuit board as follows:

1. Power down the FGA 311 and allow at least two hours for the unit to cool down to ambient temperature. Remove the cover from the enclosure, as described in *"Cover Removal and Reinstallation" on page 56*.

WARNING! **Disconnect the main power from the unit and allow at least two hours for the system to cool down before proceeding with the following steps.**

2. Remove the sensor/heater sub-assembly, as described in *"Removing the Sensor/Heater Sub-Assembly" on page 59*.
3. Pull the 3-wire connector off terminal block J3 and the 6-wire connector off terminal block J2, on the printed circuit board. Remove the sensor/heater cable assembly from the enclosure.
4. Disconnect all ground leads from the two grounding lugs on the inside of the FGA 311 enclosure.
5. Pull the 2-wire line power connector from terminal block TB1 on the PC board. In a similar manner, pull the 5-wire control signal connector from terminal block TB2 on the PC board.
6. Using a 1/4" nut driver, remove the two standoffs that secure the printed circuit board to the bottom of the enclosure.
7. Carefully pull the printed circuit board out of the enclosure. It will be necessary to angle the board slightly to work it past the two grounding lugs on the sides of the enclosure.

6.6.2 Installing the Printed Circuit Board

Refer to *Figure 21 on page 76*, for an illustration of the printed circuit board. To install the new printed circuit board, refer to *Figure 16 on page 58* and completing the following steps:

1. With the component side facing away from the enclosure, insert the PC board into the enclosure. Angle the board as required to get it past the two grounding lugs on the sides of the enclosure.
2. Secure the printed circuit board to the base of the enclosure by installing the two standoffs with a 1/4" nut driver.

IMPORTANT: *The printed circuit board can be installed in two different orientations that are rotated 180° from each other. Orient the board so that the fuse is located near the power cable.*

3. Plug the power connector and the control signal connector into terminal block TB1 and terminal block TB2 on the printed circuit board, respectively. These connectors are polarized and can only be inserted into the terminal blocks in the proper orientation.
4. Reconnect all ground leads to the two grounding lugs on the inside of the enclosure.
5. Reinstall the sensor/heater cable assembly by connecting the 3-wire connector to terminal block J3 and the 6-wire connector to terminal block J2, on the printed circuit board.
6. Install the sensor/heater sub-assembly, as described in *"Installing the Sensor/Heater Sub-Assembly" on page 60*.
7. Reinstall the cover on the enclosure, as described in *"Cover Removal and Reinstallation" on page 56*, and power up the FGA 311.

After the unit has heated up to its normal operating temperature of 700°C (about thirty minutes), data collection may be resumed.

6.7 EPROM Replacement

To permit software upgrades and to allow replacement of a damaged EPROM, the EPROM chip (U3) has been socketed on the solder side of the printed circuit board. Refer to *Figure 17* and complete the following steps to replace the EPROM:

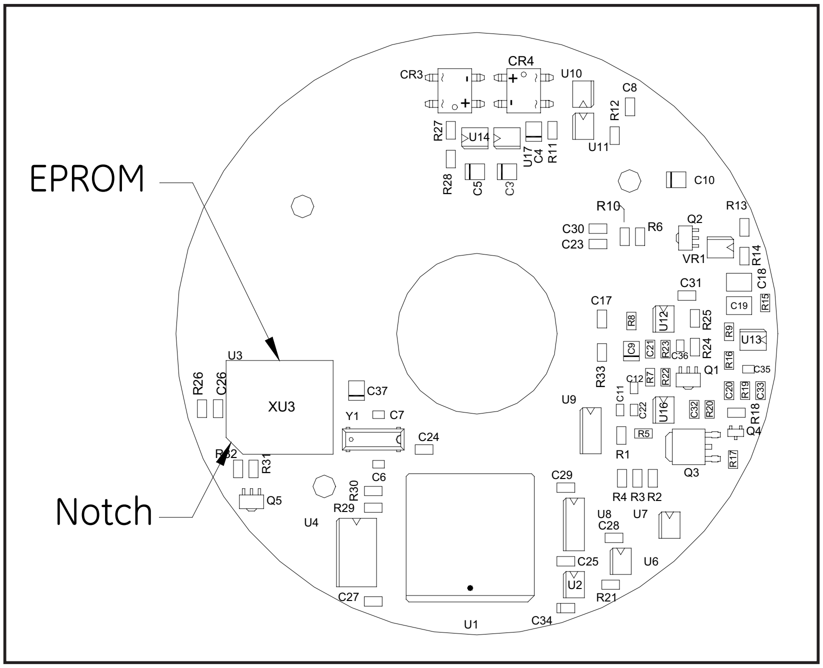


Figure 17: Solder Side of PC Board

1. Power down the FGA 311 and allow at least two hours for the unit to cool down to ambient temperature. Remove the cover from the enclosure, as described in *"Cover Removal and Reinstallation" on page 56*.

WARNING! Disconnect the main power from the unit, and allow at least two hours for the system to cool down, before proceeding with the following steps.

2. Remove the printed circuit board, as described in *"Removing the Printed Circuit Board" on page 61*.

3. Turn the printed circuit board over to the solder side and locate the socketed EPROM (U3). Using the end of a paper clip or similar object, carefully pry the EPROM (U3) out of its socket. Pry the chip out evenly by lifting it a little at a time at each of the four corners, in sequence.

6.7 EPROM Replacement (cont.)

Remove the new EPROM from its anti-static packaging, and install it by completing the following steps:

<u>CAUTION!</u> **The EPROM is easily damaged by static electricity. Before handling the chip, touch an earth ground to discharge any static electricity and install a grounding strap on your wrist. Also, avoid touching the pins on the EPROM with bare fingers, as skin oils can prevent proper electrical contact with the socket.**

1. Align the notch on the EPROM with the notch on its socket, and firmly press the EPROM into the socket on the printed circuit board until it is evenly and completely seated.

2. Reinstall the PC board, as described in *"Installing the Printed Circuit Board" on page 61*.

3. Reinstall the cover on the enclosure, as described in *"Cover Removal and Reinstallation" on page 56*, and power up the FGA 311.

After the unit has heated up to its normal operating temperature of 700°C (about thirty minutes), data collection may be resumed.

6.8 Spare Parts List

The components necessary to maintain and repair the FGA 311 are readily available from GE. The descriptions and part numbers for the major components are listed in *Table 5*.

Note: *To purchase replacement parts, have the serial number of the unit available before contacting GE.*

Table 5: Spare Parts List

Part No.	Description
214-130-02	2-Pin Terminal Block
422-011-01	Flame Arrestor Probe Tip, 316L SS
422-011-02	Flame Arrestor Probe Tip, Inconel 601
703-1216-04	Main PC Board, 115 VAC, with CJC
703-1216-05	Main PC Board, 230 VAC, with CJC
705-1028-02	Sensor Assembly, Normal Temperature, 115 VAC
705-1028-03	Sensor Assembly, High Temperature, 115 VAC
705-1028-04	Sensor Assembly, Normal Temperature, 230 VAC
705-1028-05	Sensor Assembly, High Temperature, 230 VAC
705-957-02	Filter Tip, Normal Temperature
705-957-03	Filter Tip, High Temperature
707-247	Instrument Program EPROM
098F	Flowmeter, Reference Gas, 200 psig, 20 to 400 cc/min
098C	Flowmeter, Calibration Gas, 200 psig, 0.5 to 5.0 SCFH

Chapter 7. Specifications

7.1 Performance

Accuracy:

3% of reading or 0.1% O_2

Measurement Resolution:

Analog Output: 0.01 mA

RS232 Output: 0.01% O_2

Response Time:

Less than 5 seconds for a 63% step change

Measurement Range:

Fully field-selectable via RS232 interface or on-board switches:

0–5% O_2

0–10% O_2

0–25% O_2

7.2 Operational

Process Temperature:

Standard Temperature: 150° to 650°C (300° to 1200°F)

High Temperature: 150° to 1050°C (300° to 1920°F)

Ambient Temperature (Electronics):

–20° to 70°C (–4° to 160°F)

Calibration Methods:

RS232 interface: manual via PC

Digipot adjustment: semi-automatic via push-button

Recommended Calibration Gas Mixture:

Zero Gas: 5.0% O_2, balance N_2 (depends on application and range)

Span Gas: 20.93% O_2 , balance N_2

Flow Rate: 2000 cc/min (4 SCFH)

Reference Air:

Composition: instrument air (20.93% O_2), regulated to 3 psi (20 kPa)

Flow Rate: 20 to 50 cc/min (0.04 to 0.11 SCFH)

7.3 Functional

Output:

4–20 mA Analog Output: isolated, 600 ohm maximum

Digital Output: RS232 communications

Input Power:

115 VAC

230 VAC

Power Consumption:

75 W

Process Connection:

Standard: 1 1/2” NPTM

Optional: 2” and larger flanges

7.4 Physical

Materials of Construction:

Enclosure: Epoxy-coated aluminum

Probe (Standard Temperature): 316 SS process wetted or welded parts

Probe (High Temperature): Inconel® alloy process wetted or welded parts

Probe Lengths:

19”

1 m

1.5 m

2 m

Probe Weight:

19” Probe: 6.8 kg (15 lb)

Probe Mounting:

Orientation: vertical or horizontal, 1 1/2” NPT

Type: flange (available in most common sizes)

Hazardous Area Certifications:

Weatherproof: NEMA-4X, IP66

Explosion-proof / Flameproof:

C_US Certification No. 1622936

Class I, Div. 1, Groups B, C, D

T6 (electronic housing)

T4 (sensor probe)

ISSeP02ATEX028 X, Electronics:

II 2 GD EEx d IIB T6

ISSeP02ATEX028 X, Process:

II 2 GD d IIB T2

European Compliance:

Complies with EMC Directive 2004/108/EC and LVD Directive 2006/95/EC (Installation Category II, Pollution Degree 2) and PED 97/23/EC for DN<25.

Appendix A. The Nernst Equation

A.1 Introduction

The FGA 311 In Situ Flue Gas Oxygen Transmitter uses the *Nernst Equation* to calculate the oxygen content of the flue gas. When a Yttrium-doped zirconium oxide ceramic is heated to a temperature above 650°C, it becomes an electrolytic conductor, as vacancies in the crystal lattice permit oxygen ions to diffuse into the ceramic.

If there are different oxygen partial pressures on the two sides of the ceramic cell, oxygen ions will migrate along the resulting *concentration gradient*. This constitutes a transfer of electrons from one face of the ceramic to the other. If the transferred charge is allowed to accumulate, it gives rise to a *potential gradient* acting in the opposite direction, thus tending to oppose further diffusion.

A.2 Equilibrium Conditions

Under equilibrium conditions, the potential gradient exactly balances the concentration gradient. Porous coatings of a platinum catalyst on both surfaces of the ceramic cell serve as electrodes, while still allowing the oxygen molecules to penetrate the coating and diffuse into the ceramic. The measured voltage drop across the cell can be directly related to the ratio of the two oxygen partial pressures by means of *Equation 3*, the *Nernst Equation*:

$$E_{12} = \frac{RT}{nF} \bullet \ln\left[\frac{p_1}{p_2}\right] \tag{3}$$

where,

F = the Faraday = 96,484.56 coulombs

T = absolute temperature = °K

R = gas constant = 8.31441 volt-coulomb/mole-°K

n = # electrons transferred per molecule = 4/mole

ln = natural logarithm = 2.303 $\log_{10}$

p_1 = O_2 partial pressure on reference gas side = 0.2093

p_2 = O_2 partial pressure on flue gas side

E_{12} = voltage on reference face with respect to the flue gas face

A.3 The FGA 311

The *Nernst Equation* specifically applicable to the FGA 311 analyzer is obtained by substituting the parameter values in the previous section into the general equation, converting the natural logarithm (base e) to the common logarithm (base 10) and converting the units for E_{12} to millivolts. This results in *Equation 4*.

$$E_{12}(\mathrm{mV}) = 0.049605 \bullet T \bullet \log\left[\frac{0.2093}{p_2}\right] \tag{4}$$

The FGA 311 measures the temperature at the sensor and automatically inserts the correct value into the Nernst Equation. For example, at the usual operating sensor temperature of 700°C, *Equation 5* is used.

$$E_{12}(\mathrm{mV}) = 48.274 \bullet \log\left[\frac{0.2093}{p_2}\right] \tag{5}$$

The voltage drop across the zirconium oxide sensor, as calculated from the *Equation 5*, is then sent to the linearizer circuit. This circuit produces a linear 4-20 mA output that represents the percentage of oxygen in the flue gas, and this signal is available to the user at pins 4-5 of terminal block TB2 on the printed circuit board.

Appendix B. FGA 311 Drawings

For reference, the following drawings are included in this appendix:

[no content intended for this page]

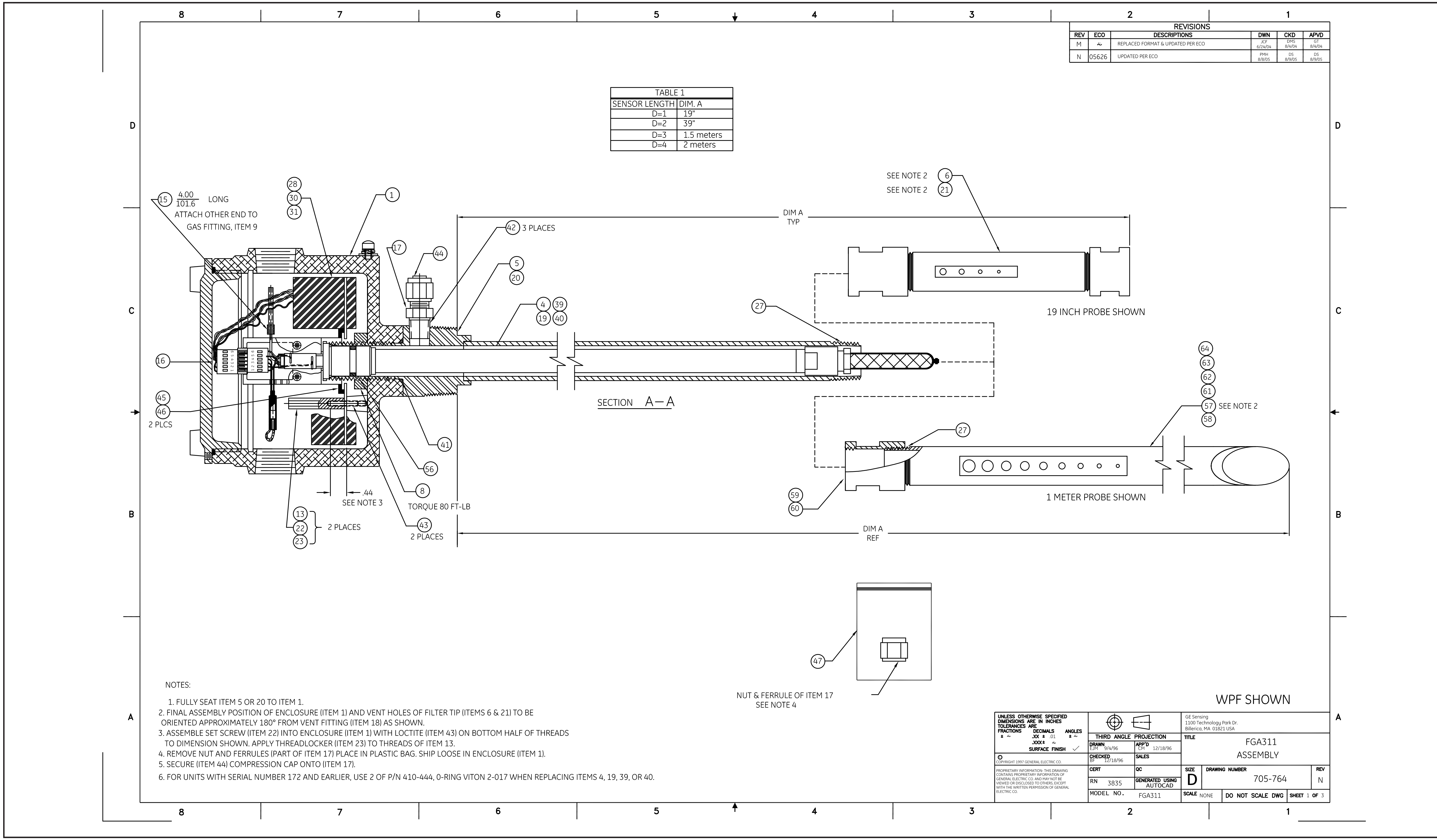


Figure 18: FGA 311 Weatherproof Assembly (Drawing 705-764_rev N, Sheet 1)

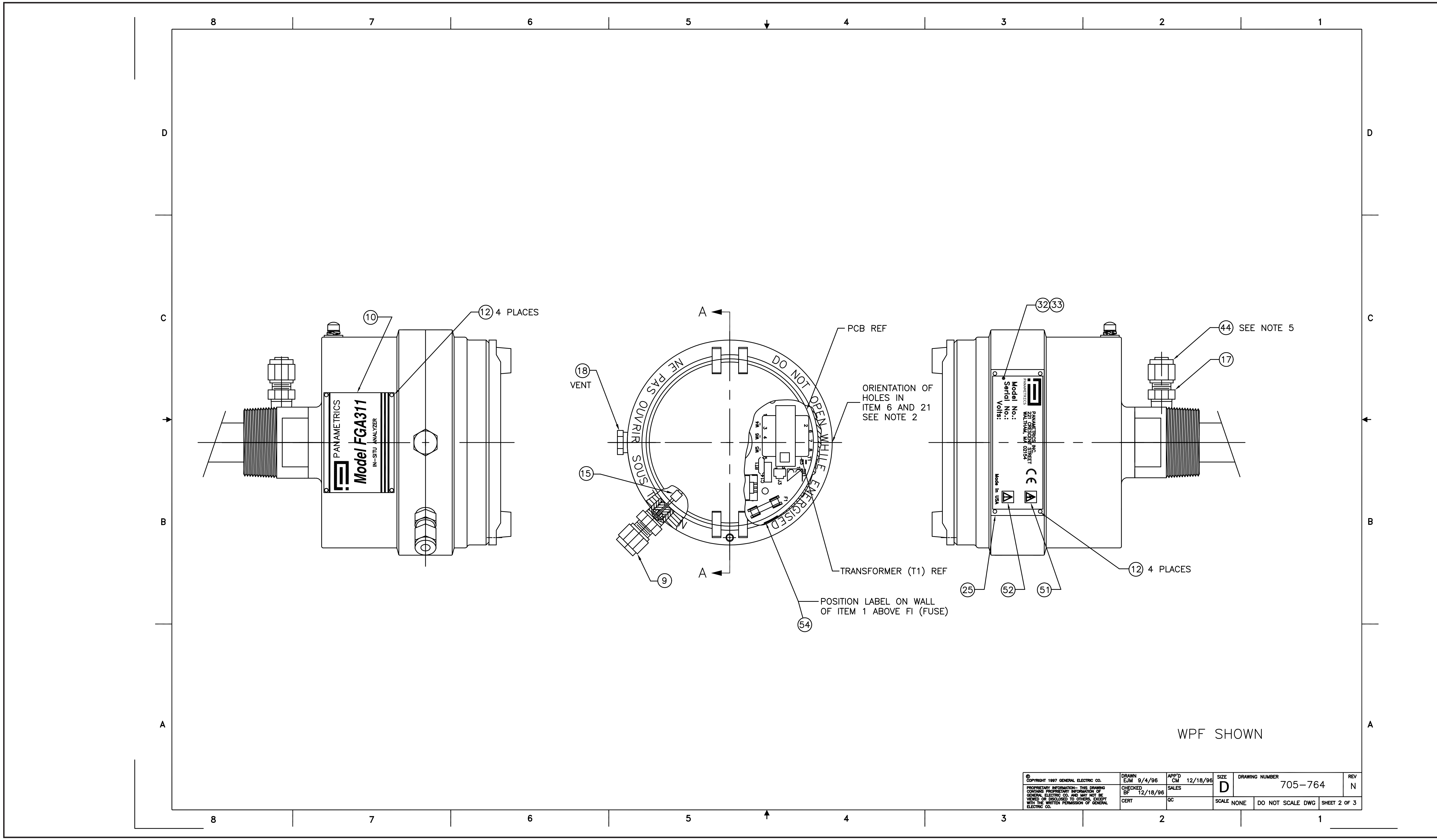


Figure 19: FGA 311 Weatherproof Assembly (Drawing 705-764_rev N, Sheet 2)

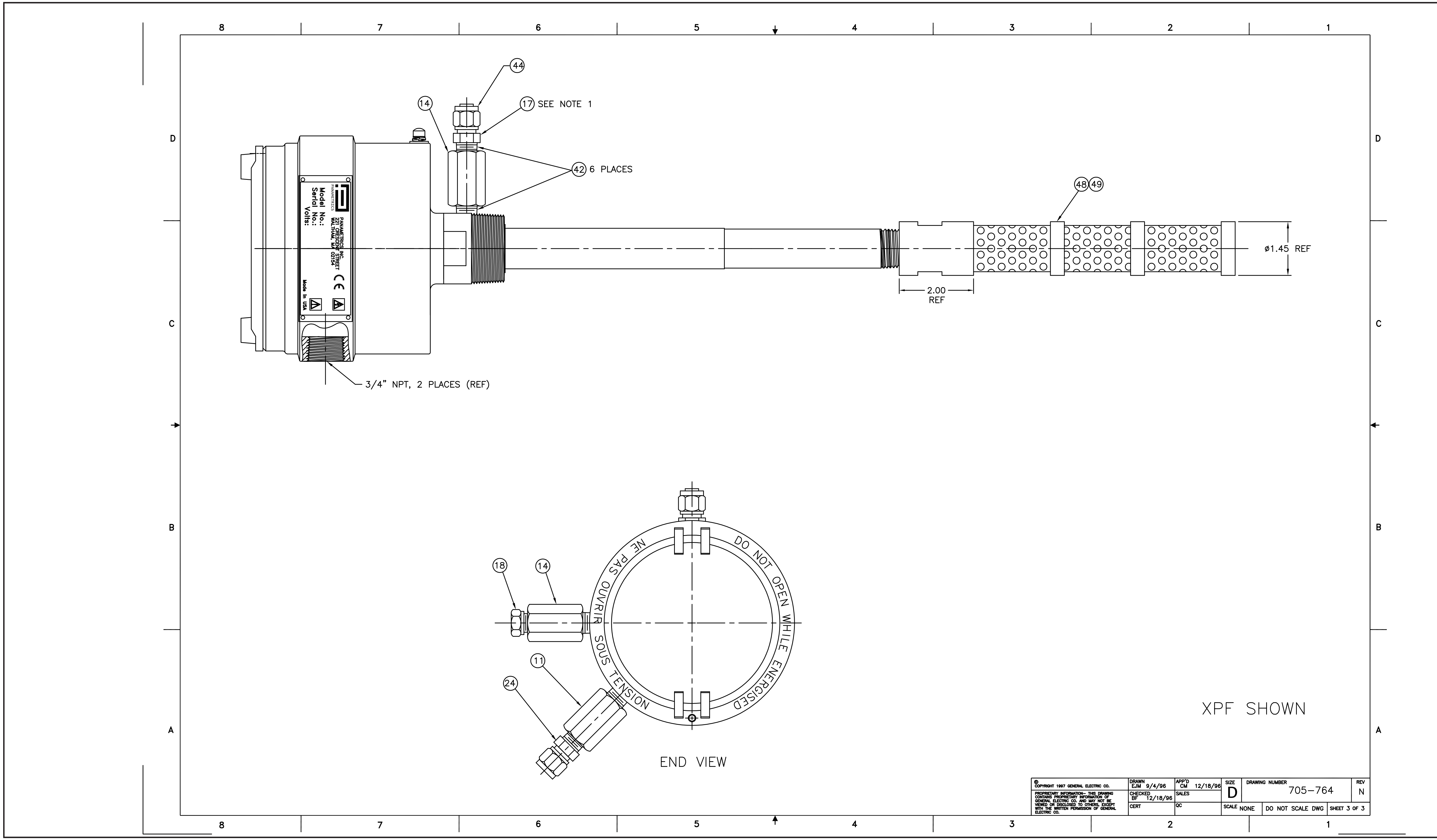


Figure 20: FGA 311 Explosion-Proof Assembly (Drawing 705-764_rev N, Sheet 3)

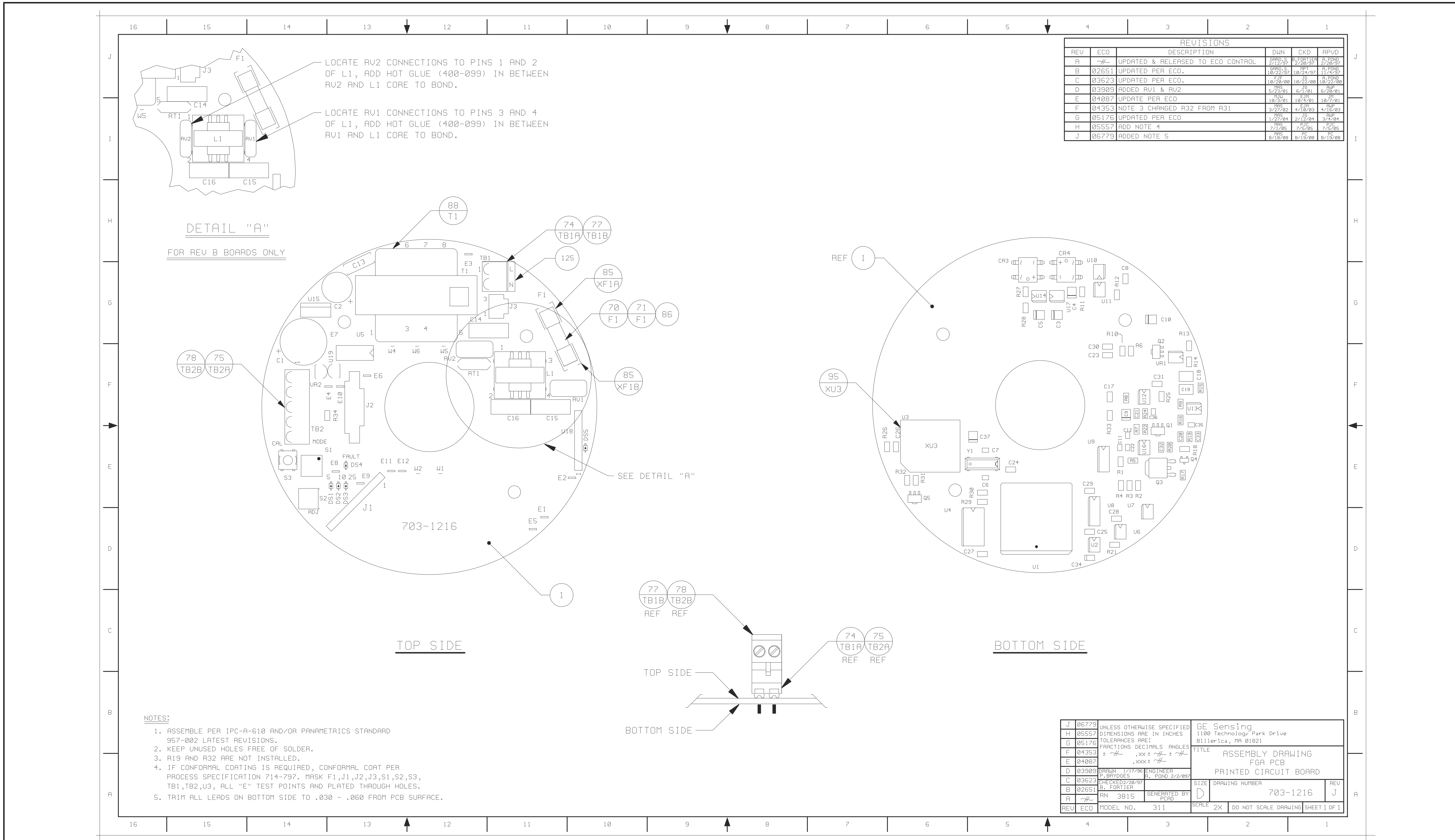


Figure 21: FGA 311 Printed Circuit Board (Drawing 703-1216_rev J

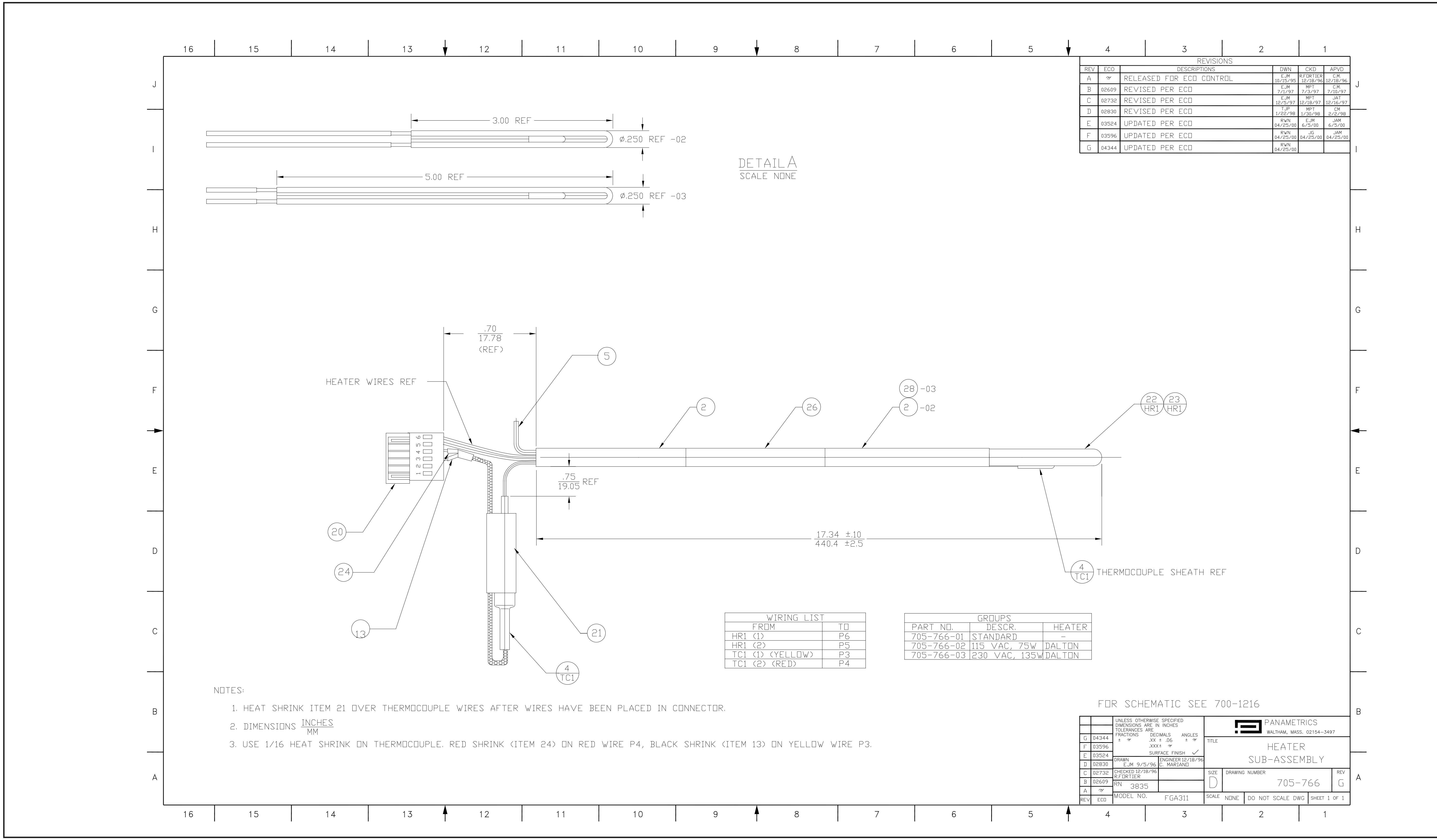


Figure 22: FGA 311 Heater Assembly (Drawing 705-766_rev G)

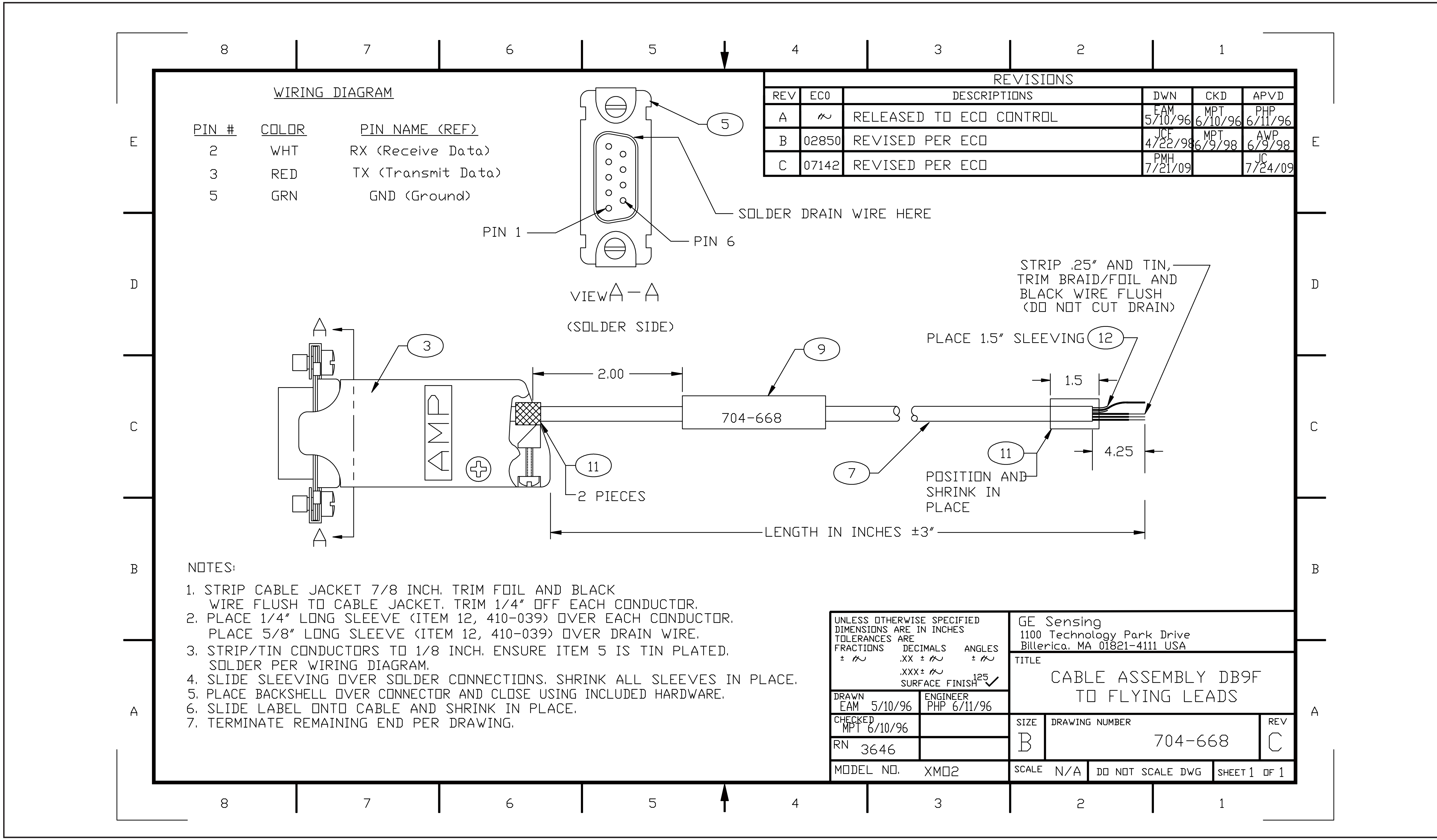


Figure 23: RS232 Cable Assembly (Drawing 704-668_rev C)

Appendix C. CE Mark and Regulatory Compliance

C.1 CE Mark Compliance

For CE Mark compliance, the FGA 311 must meet both the *EMC* and *LVD* directives.

WARNING! CE MARK COMPLIANCE IS REQUIRED FOR ALL UNITS INSTALLED IN EU and EEA COUNTRIES.

C.1.1 EMC Directive

WARNING! TO MEET CE MARK REQUIREMENTS, YOU MUST SHIELD AND GROUND ALL ELECTRICAL CABLES AS DESCRIBED IN THIS SECTION (see *Table 6*).

Note: *If you follow the instructions in this section, your unit will comply with the 2004/108/EC EMC Directive.*

Table 6: Wiring Requirements for CE Mark Compliance

Connection	Termination Modification
Power/Analog Output	1. When connecting the line power/analog output cable, select the cable entry closest to the terminal blocks. 2. Use shielded cable*, such as GE P/N X4(*) or equivalent, to connect the line power and the 4-20 mA analog output device to the FGA 311. 3. Terminate the shield to the recommended cable gland, GE P/N 419-215.
RS232 Output	1. Use shielded cable*, such as GE P/N 704-668-12 or equivalent, to interconnect the FGA 311 enclosure with any external I/O devices. 2. Terminate the shield to the recommended cable gland, GE P/N 419-215.
*Wires enclosed in a properly-grounded metal conduit do not require additional shielding.	

WARNING! Cable entries of an approved flameproof design are required. These must be installed according to the manufacturer's instructions. The choice of cable entry device may limit the overall installation category achieved.

WARNING! It is the responsibility of the user to ensure that all cable entry devices and covers are properly installed and secure prior to applying power to the XMTC.

C.1.2 LVD Directive

For compliance with the LVD directive the FGA 311 requires an external power disconnect device such as a switch or circuit breaker. The disconnect device must be marked as such, clearly visible, directly accessible, and located within 1.8 m (6 ft) of the FGA 311. It must be clearly marked as being the disconnect device for the analyzer.

Note: *If you follow the instructions in this section, your unit will comply with the 2006/95/EC LVD Directive, with the following exception: the 230 VAC unit passes with a test voltage of 1,800 VAC (refer to Table D.10 of Annex D in EN61010).*

[no content intended for this page]

Appendix D. Data Records

D.1 General Information

Enter the general information about your FGA 311 and its installation in *Table 7*.

Table 7: General Information

Parameter	Current Value
Installation Date:	
Unit Model Number:	
Unit Serial Number:	
Line Voltage:	
Oxygen Range Setting:	
Reference Air Composition:	
Reference Air Flow Rate:	
Calibration Gas Composition:	
Calibration Gas Flow Rate	
Application Description:	

D.2 User Settings

Enter the current user settings that are programmed into the FGA 311 *User Program* in *Table 8*.

Table 8: User Settings

Menu Option	Current Setting
AIR:	
O2_RNG:	
COM:	
ER1_SET:	
ER2_SET:	
ER3_SET:	
ER4_SET:	
PID (SET):	
PID (P):	
PID (I):	
PID (O):	

D.3 Test and Calibration Data

The zirconium oxide oxygen sensor in the FGA 311 should be *tested* and *calibrated* on a regular schedule. Enter your test and calibration data in *Table 9* and *Table 10*, respectively.

Table 9: Oxygen Sensor Tests

Test Date	Result

Table 10: Oxygen Sensor Calibrations

Calibration Date	Result

D.4 Service Record

All service procedures, excluding normal routine maintenance, performed on the FGA 311 should be recorded in *Table 11*.

Table 11: Service Record

Date	Service Performed

[no content intended for this page]

Appendix E. Advanced Calibrations

E.1 Duty Cycle/ Offset

The offset value is subtracted from the “Raw O2 mV” value with the difference showing in the “O2 mV” value. The amount of duty cycle/offset table entries can range from 0 to 5 and they do not have to be entered in any type of order. The calculation of the offset value to subtract depends on the following cases:

1. **One duty cycle/offset entry only:** The offset entry in this case will be used universally, that is, the same offset will be used no matter what the duty cycle.
2. **More that one activated entry and measured duty cycle falls between two entered duty cycle values from the table:** The software will choose the closest duty cycle values above and below the measured duty cycle. The offset value will be interpolated based on the chosen entries.
3. **Measured duty cycle value falls above or below any table value:** The offset value will clamp to the lowest or highest table entry in terms of duty cycle.
4. **No entry activated or whole table de-activated:** The offset value will be zero.

COM ERR PID FRZ RESP [OFST]	Press [SPACE] to select “OFST” and then press [ENTER].

Use Offset Table YES [NO]	Observe the Offset enable Yes/No menu and press the “D” key.

Run time data should appear or disappear depending on the prior setting. Selecting “NO” from the offset enable choices will give a message of “DUTY CYCLE OFFSET TABLE ENABLED.” No table should appear below (that is, if “D” had been pressed to clear any previous display of the table).

Use Offset Table [YES] NO	Press [SPACE] to select “YES” and then press [ENTER].

The offset table should appear at the bottom of the screen. The offset table gives the user entered Duty Cycle values with their corresponding offset values. Also the line above the table headers should read that the offset is enabled in addition to displaying the current % duty cycle reading and the calculated offset value.

E.1 Duty Cycle/ Offset (cont.)

DC/Ofst Entries [1] 2 3 4 5	Select number “1” from the DC/Offset Entries menu and press [ENTER].
Use Entry 1 [YES] NO	Select “Yes” for Use Entry 1 and press [ENTER].

Choosing “Yes” activates a DC/Offset entry and will be used for offset calculations. The table entry for entry 1 should now show “Enabled.” The offset reading above the table should now display a value other than zero.

Entry 1 [DC] Offset	To change the DC value, select “DC” and press [ENTER].
Entry 1 DC [Offset]	To change the Offset value, select “Offset” and press [ENTER].

All entries (1-5) are edited in the same way. Press [ESC] to return to run mode.

[no content intended for this page]

Warranty

Each instrument manufactured by GE Sensing is warranted to be free from defects in material and workmanship. Liability under this warranty is limited to restoring the instrument to normal operation or replacing the instrument, at the sole discretion of GE Sensing. Fuses and batteries are specifically excluded from any liability. This warranty is effective from the date of delivery to the original purchaser. If GE Sensing determines that the equipment was defective, the warranty period is:

- one year from delivery for electronic or mechanical failures
- one year from delivery for sensor shelf life

If GE Sensing determines that the equipment was damaged by misuse, improper installation, the use of unauthorized replacement parts, or operating conditions outside the guidelines specified by GE Sensing, the repairs are not covered under this warranty.

The warranties set forth herein are exclusive and are in lieu of all other warranties whether statutory, express or implied (including warranties or merchantability and fitness for a particular purpose, and warranties arising from course of dealing or usage or trade).

Return Policy

If a GE Sensing instrument malfunctions within the warranty period, the following procedure must be completed:

1. Notify GE Sensing, giving full details of the problem, and provide the model number and serial number of the instrument. If the nature of the problem indicates the need for factory service, GE Sensing will issue a RETURN AUTHORIZATION NUMBER (RAN), and shipping instructions for the return of the instrument to a service center will be provided.
2. If GE Sensing instructs you to send your instrument to a service center, it must be shipped prepaid to the authorized repair station indicated in the shipping instructions.
3. Upon receipt, GE Sensing will evaluate the instrument to determine the cause of the malfunction.

Then, one of the following courses of action will then be taken:

- If the damage <u>is</u> covered under the terms of the warranty, the instrument will be repaired at no cost to the owner and returned.
- If GE Sensing determines that the damage <u>is</u> <u>not</u> covered under the terms of the warranty, or if the warranty has expired, an estimate for the cost of the repairs at standard rates will be provided. Upon receipt of the owner's approval to proceed, the instrument will be repaired and returned.

[no content intended for this page]

GE
Sensing

ATEX COMPLIANCE

We,

GE Sensing
1100 Technology Park Drive
Billerica, MA 01821
USA

as the manufacturer, declare under our sole responsibility that the

FGA 311 In Situ Flue Gas Oxygen Transmitter

to which this declaration relates, in accordance with the provisions of ATEX Directive 94/9/EC Annex II, meets the following specifications:

CE 1180 Ex II 2 GD EEx d IIB T2
ISSeP02ATEX028X T95°C IP66 (Housing)

Furthermore, the following additional requirements and specifications apply to the product:

- Having been designed in accordance with EN 50014, EN 50018, and EN 50281, the product meets the fault tolerance requirements of electrical apparatus for category "d".
- The product is an electrical apparatus and must be installed in the hazardous area in accordance with the requirements of the EC Type Examination Certificate. The installation must be carried out in accordance with all appropriate international, national and local standard codes and practices and site regulations for flameproof apparatus and in accordance with the instructions contained in the manual. Access to the circuitry must not be made during operation.
- Only trained, competent personnel may install, operate and maintain the equipment.
- The product has been designed so that the protection afforded will not be reduced due to the effects of corrosion of materials, electrical conductivity, impact strength, aging resistance or the effects of temperature variations.
- The product cannot be repaired by the user; it must be replaced by an equivalent certified product. Repairs should only be carried out by the manufacturer or by an approved repairer.
- The product must not be subjected to mechanical or thermal stresses in excess of those permitted in the certification documentation and the instruction manual.
- The product contains no exposed parts which produce surface temperature infrared, electromagnetic ionizing, or non-electrical dangers.
- The setting of the electronic protective device ensuring that the temperature class indicated in this certificate is fulfilled shall be affected for each apparatus under the responsibility of the manufacturer. Furthermore, this setting shall not be modified.

[no content intended for this page]

GE
Sensing

DECLARATION OF CONFORMITY

DOC-0035, Rev. A

We,

GE Sensing
1100 Technology Park Drive
Billerica, MA 01821
USA

declare under our sole responsibility that the

FGA300H and FGA300HX Horizontal Flue Gas Analyzers
FGA300V and FGA300VX Vertical Flue Gas Analyzers
FGA300D Display Unit
FGA311 In Situ Flue Gas Oxygen Analyzer

to which this declaration relates, are in conformity with the following standards:

- EN 61326-1: 2006, Class A, Table 2, Industrial Locations
- EN 61326-2-3: 2006
- EN 61010-1: 2001, Overvoltage Category II, Pollution Degree 2

following the provisions of the 2004/108/EC EMC and 2006/95/EC Low Voltage Directives.

The units listed above and any ancillary equipment supplied with them do not bear CE marking for the Pressure Equipment Directive, as they are supplied in accordance with Article 3, Section 3 (sound engineering practices and codes of good workmanship) of the Pressure Equipment Directive 97/23/EC for DN<25.

Billerica - August 2010
Issued

Mr. Gary Kozinski
Certification & Standards, Lead Engineer

Customer Support Centers

U.S.A.

The Boston Center
1100 Technology Park Drive
Billerica, MA 01821
U.S.A.
Tel: 800 833 9438 (toll-free)
978 437 1000
E-mail: sensing@ge.com

Ireland

Sensing House
Shannon Free Zone East
Shannon, County Clare
Ireland
Tel: +353 (0)61 470291
E-mail: gesensingsnnservices@ge.com

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